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Development of a 2nd Generation Topographical Map Display (ToMaDi MkII)

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Abstract

This technical memorandum describes in detail the development of a 2nd generation Topographical Map Display (ToMaDi MkII). The ToMaDi MkII display system is an evaluation prototype, made from a 4 by 4 matrix of colour Thin Film Transistor - Liquid Crystal Display (TFT-LCD) and designed to study alternatives to topographical paper maps for Command and Control (C&C) applications. Because ToMaDi MkII is a touchscreen computer display, it contributes to the digitization of the battlefield project. The brightness, contrast ratio and viewing angle are similar to those of a Cathode Ray Tube (CRT) display. But, contrarily to CRT, its shallow depth allows its usage in confined locations while maintaining a high portability. Up to now, the MkII prototype has shown very good characteristics that allow its use in specific operational scenarios. The value of ToMaDi MkII was confirmed by its utilization in three major military exercises. In summary, the ToMaDi MkII makes electronic mapping a reality.

Résumé

Ce mémorandum technique décrit de façon détaillée la réalisation d'un système d'affichage électronique pour cartes topographiques de seconde génération (AfCaTo MkII). Celui-ci est un prototype d'évaluation, constitué d'une mosaïque de seize écrans couleurs à cristaux liquide à matrice active. Il a été conçu pour étudier une solution de rechange à l'utilisation des cartes topographiques en papier pour les applications de commandement et contrôle. Comme c'est un affichage d'ordinateur à écran tactile, il contribue au projet de numérisation du champ de bataille. Sa brillance, son contraste et son angle de vision sont semblables à ceux des affichages à tubes à écran cathodique (TEC). Cependant, contrairement aux TEC, sa faible profondeur permet un transport facile et une utilisation dans les endroits exigus. Jusqu'à maintenant, le prototype MkII a démontré d'excellentes caractéristiques qui lui permettent d'être utilisé dans des scénarios opérationnels particuliers. La valeur de l'AfCaTo MkII a été confirmée par son utilisation dans le cadre de plusieurs exercices militaires. En résumé, le ToMaDi MkII fait de la cartographie électronique une réalité.

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Executive summary

The recent progress in the computer science domain allowed the development of tactical information processing systems which are very powerful, dependable and relatively cheap. The Canadian Forces (CF) have been developed information processing systems to increase the efficiency of sea, land, air and joint operational centres for their C&C tasks. Unfortunately, despite the usage of powerful computer systems, the military staff still rely heavily on the use of paper maps and milar traces on which they annotate the operational / tactical situation. Moreover, because of the operations spatial extent or the displacement of a localized tactical operation in time, many map sheets are needed and require much space on the walls and tables in a command post. To solve these problems of map annotation and paper map manipulation in an exiguous space, the usage of large electronic high-resolution Flat Panel Display (FPD) could be considered. Such kind of display would have the following advantages: make the C&C Information System (CCIS) digital from end to end; allow the visualization of many maps in exiguous locations; allow the visualization of the same tactical information along the chain of command.

Defence R&D Canada – Valcartier (DRDC Valcartier) has undertaken several projects to design and develop new C&C decision aids. One of them is the All-Source Intelligence Producer (ASIP). This project involves the development of a data processing system based on a network of PC workstations and a SUN server linked together by an Ethernet link. The second generation ToMaDi is one of the component of this system and is meant to highlight the benefits of large and flat panel display technology in a command post.

This memorandum describes the development of the ToMaDi MkII display which comprises a touch sensitive display unit made of a mosaic of sixteen TFT-LCD linked with a PC workstation. The global setup, designed and built in many parts by the author with affordable Commercial off-the-shelf (COTS) components, should be considered as an evaluation prototype since it is not the final solution to all of the above mentioned problems. However, the work carried out for this project is the second step of a global process which may lead to the production of a fieldable integrated decision aid console.

This work is directly relevant to the CF requirements, and applicable to present and future CCIS.

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Sommaire

Les progrès récents en informatique ont permis de développer des systèmes de traitement de l'information tactique à la fois puissants et fiables, et ce à un coût relativement peu élevé. Ainsi, les Forces canadiennes (FC) ont mis au point des systèmes de traitement de l'information dans le but d'accroître l'efficacité des tâches de commandement et contrôle (C^2) des centres des forces navales, terrestres, aériennes et des opérations interarmées. Même s'il disposent d'ordinateurs puissants, les militaires continuent de faire grand usage de cartes en papier et de transparents où figurent leurs annotations sur la situation opérationnelle/tactique. Par ailleurs, en raison de l'étendue des opérations ou de la progression dans le temps d'une opération tactique locale, on a besoin d'un grand nombre de cartes en papier, ce qui occupe beaucoup d'espace sur les murs ou les tables du poste de commandement. La solution aux problèmes liés à l'annotation ou la manipulation de cartes en papier dans un espace restreint réside peut-être dans l'utilisation d'un écran d'affichage plat à haute résolution. Ce type d'écran possède une foule d'avantages : il permet de numériser entièrement les systèmes d'information du C^2 (SICC); d'afficher un grand nombre de cartes dans un espace restreint; et de visualiser la même information tactique tout au long de la chaîne de commandement.

Recherche et développemnent pour la défense Canada (RDDC) - Valcartier a entrepris plusieurs projets visant à concevoir et mettre au point de nouveaux systèmes d'aide à la décision en C^2. L'un de ceux-ci est le centre de production du renseignement multisource qui vise à mettre sur pied un système de traitement des données basé sur un réseau d'ordinateurs PC reliés entre eux au moyen d'un serveur Sun via un lien Ethernet. La 2e génération de ToMaDi est l'une des composantes du système. Celle-ci est destinée à mettre en relief les avantages de l'utilisation de la technologie des grands écrans d'affichage plats dans un poste de commandement.

Ce mémorandum décrit le ToMaDi MkII, lequel comporte un écran tactile formé d'une mosaïque de seize écrans à cristaux liquides reliés à un PC. La configuration d'ensemble, conçue et réalisée en grande partie par l'auteur grâce à des composantes disponibles à prix abordable sur le marché, doit être perçue comme un prototype, puisqu'elle n'est pas la panacée à tous les problèmes énoncés ci-dessus. Le travail effectué dans le cadre ce projet constitue la deuxième étape d'un processus d'ensemble qui pourra permettre la mise en service d'un pupitre intégré d'aide à la décision.

Ce travail répond directement aux besoins des FC et SICC actuels et futurs.

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1.0 INTRODUCTION

In operation centers or command posts, maps are the main elements used to depict the global situation. Nowadays, topographical paper maps are still largely used and they make it possible to depict information down to small terrains or tactical features. The rapid expansion of computer processing power and storage, as well as the improvement of electronic displays, in terms of size and resolution, have fostered the development of more and more complex electronic map display and geographic information system applications. Despite the widespread use of electronic displays, topographical paper maps are still largely used, because electronic displays have significant limitations in terms of size and visual characteristics, which prevent them to totally supersede paper maps (Ref. 1).

However, for the last twenty years, advanced panel display devices like LCD have made so much progress that they now represent good alternatives to topographical paper maps. These display technologies provide the users with flat panels and good visual characteristics. The main limitation still remains the total size of the display viewing area (Ref. 2). A solution to increase display size is to build a mosaic of FPDs. This was the purpose of the ToMaDi project. As a first experimentation, four Fujitsu Plasma Display Panels (PDP) were put in a 2 x 2 configuration to reach a global size of 42" in diagonal, which was enough to display most 1:50 k topographical maps (Ref. 3). The "tiling" approach, which had many advantages, was used because no FPD of that size (with a satisfactory resolution) was available at the beginning of the project. This is still the case nowadays.

Section 2 describes what would be an ideal topographical map display. In Section 3, a review of large multi-display available on the market is done. In Chapter 4, all the aspects related to the ToMaDi MkII hardware implementation are presented. In Chapters 5, 6 and 7, the difficulties encountered during the making, military utility assessment and lessons learned from the ToMaDi MkII usage are discussed, respectively. In the last chapter, based on the ToMaDi's weaknesses, suggestions for improvement are examined and lay out the path to future work in this domain.

This work was performed at DRDC Valcartier under unit 2kr13, New Media, between April 1999 and December 2000.

2.0 MAP DISPLAY CRITERIA

Topographical maps used in command posts are generally of great dimensions and contain detailed terrain information. Some of them are monochrome, but most maps use various shades of colours, such as green, light green, brown, red, light red, blue, light blue and black. As a consequence, a FPD used to display such maps should have a colour capacity of at least 8 bits per pixel.

If different kinds of symbols have to be layered on the map or any kind of graphical information has to be displayed (B/W and colour aerial / satellite photography, video sequences, etc.), 18, 24 or more bits per pixel would be better. In military operations at the tactical level, the mostly used topographical maps have a scale of 1 to 50 k (1:50 k). At this ratio, the largest paper map sheets have a size of 30" x 22". For this reason, a FPD used to display any kind of 1:50 k map should have an effective visual display size bigger than 30" x 22". The last but not the least factor, a topographical map contains a great deal of small details like fine lines, small symbols (i.e. swamp). This characteristic is very important, since military who work with maps absolutely require the same level of detail on a FPD or a map. To illustrate the effect of the local resolution of an image, usually expressed in dots per inch (dpi), a portion of a digitized 1:50 k topographical map at four different resolutions is illustrated in Figure 1. The map was originally scanned at 600 dpi. Clearly, those displayed at 300 and 100 dpi are sufficiently resoluted to be displayed on a FPD. At 75 dpi and below, the fine details become unrecognizable and therefore unusable. As a consequence, the local resolution of the chosen display would be as high as possible, but should not be less than 80 dpi.

The above criteria constitutes the guidelines for the design of the display unit dedicated for topographical maps visualization. In order to increase its effectiveness, the addition of a touchscreen capability would be a desirable feature. Since this characteristic is not an absolute necessity, its presence would allow the commanders to interact directly with the displayed information (without neither keyboard nor mouse). As a result, the reaction time would be reduced significantly. This is a good thing since this characteristic becomes a more and more important aspect in C&C operations.

3.0 REVIEW OF LARGE TILED MULTI-DISPLAY TECHNOLOGY

In order to obtain a large electronic display, several solutions are available on the market. One of the most classical ways to obtain this kind of display is to stack many rows of rear projection cubes. An example of this kind of technology is illustrated in Figure 2(a) (Ref. 4). Many companies produce this kind of large display. In addition to Pioneer Corp. which produced the one in this figure, there are also Electrosonic, Toshiba, Sony and Clarity Visual Systems, to name only a few. Each projection cube has a front projection screen back-driven by an internal projector. Any kind of electronic projector can be used to do so (CRT, LCD or Digital Micromirror Device[1] (DMD)). Since the rear-projected image can use the whole part of the screen's available display area, the global image is almost seamless. This technology is scalable and the global display can be as big as required. However, each cube is heavy, consume much electrical power, has significant depth and a low local resolution (< 40 pixels per inch (ppi), depending on the size of the screen). More- over, no touchscreen capability is offered. More recently, National Display Systems (NDS) proposed a tiled multi-display system named CUBE and shown in Figure 2(b) (Ref. 5). Each element is a TFT-LCD[2] and the global display can be as large as required. Since each tile is an 18.1" 1280 x 1024 TFT-LCD, device weight, power consumption and depth are low. The local resolution is high (90 ppi) and no touchscreen capability is provided. The main disadvantage of this approach is the presence of wide horizontal and vertical black borders between the active displayed images, hereafter named mullion[3], of 31.5 and 32 mm, respectively. This makes uncomfortable the vision of the image displayed. Another company, Panoram Technologies, produce some 3 x 1 tiled TFT-LCD displays. Their mullions are thinner (11 and 19 mm), but their image sizes are limited and not expandable (Ref. 6).

For a military environment, General Dynamics Corp. used the same approach as NDS and produced a ruggedized modular tiled display array named V2 and shown in Figure 3 (Ref. 7). It possesses the same characteristics as the CUBE's, including large mullions, and it is sufficiently rugged for military applications. The touchscreen option is not available for the "CUBE" and the "V2" for the moment but it is technically possible by adding one transparent touchscreen layer on every LCD. By doing so, feature selection

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1. Trade mark of Texas Instruments
2. The acronym AM-LCD (Active Matrix - LCD) is also used to designate this kind of FPD.
3. The term «grout» is also frequently used in the electronic display domain.

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and the double clicking action can be easily performed, but the dragging operation would be disturbed when a mullion has to be crossed over.

In the year 2000, Rainbow Displays Inc., in cooperation with Philips Flat Display Systems, developed a technology capable of producing true seamless (no mullion at all!) tiled multi-LCD displays. This dramatic improvement in the multi-display domain was obtained by putting side by side LCD panels having lines and columns drive interconnections on one side at the periphery. Since it is possible to remove entirely the mullion around the LCD where there are no interconnection, it is possible to produce large LCD displays by using four panels (for a 2 x 2 configuration) and three panels (for a 1 x 3 configuration), as shown in Figure 4 (a) and (b), respectively (Ref. 8).

Because each tile is a LCD panel, weight, power consumption and depth are low. The local resolution is low (26 ppi), but this technology can lead to a much higher level of local resolution (>90 ppi). No touchscreen capability is provided. The main disadvantage of this approach is the necessity of leaving the interconnection side of each panel at the periphery of the global display. As a consequence, it is only possible to produce tiled display with 1 x N or 2 x N configuration. If a 3 x 3 or 4 x 4 configuration is required to have a large enough and locally resoluted global display for a specific application, other technologies should be used.

This survey of available technology for large multi-tiled display showed that there are no "silver bullet" solution to display visually comfortable topographical maps at a sufficient local resolution with easy-to-use touchscreen capability, while having low weight, power consumption and depth. Conversely, DRDC Valcartier developed the two generations of ToMaDi prototypes. The following sections will elaborate in detail on the design and characteristics of these novel prototypes.

4.0 THE ToMaDi PROJECT

The ToMaDi project started in 1997 and was aimed at studying alternatives to paper maps for C&C applications. It investigated better ways to present information to commanders by using a mosaic of electronic display screens to present a macroscopic view of a situation rather than the more microscopic view allowed by conventional single display screens. The first system to be developed was mainly constituted with a display unit made

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from a mosaic of four 21" colour Fujitsu PDPs put in a 2 x 2 configuration, and a PC Pentium Pro/200MHz/NT4 workstation using dedicated video interfaces made by Colorgraphics. This system was named ToMaDi and is illustrated in Figure 5.

4.1 The ToMaDi MkII Prototype

The second generation prototype was built between April and December 1999 and named ToMaDi MkII. The ToMaDi MkII system is mainly constituted of a display unit made from a mosaic of sixteen 14.1" diagonal colour LG-Philips TFT-LCDs put in a 4 x 4 configuration, a touchscreen digital board and a PC Pentium III/550MHz/NT4 workstation using Enseo dedicated video interfaces. It has a total power consumption of approximately 500 W, including the PC. The complete setup and system diagram are shown in Figures 6 and 7. The principals assembly drawings are shown in Appendix A.

The total resolution and display size, obtained by the combination of the sixteen TFT-LCDs are 4096 x 3072 pixels and 59" diagonal, respectively. The full colour capability (18 bits), brightness of 120 cd/m2, contrast of 250:1 and usable viewing angle of 90° horizontally and 40° vertically are the noticeable advantages. They allow to display a 30" x 22" 1:50 k topographical map in real size with a local resolution of 91 ppi and leave a lot of room for different other applications on the desktop. This value of 91 ppi, which is higher than the 80 ppi stated previously, allows to see the fine details of 1:50 k topographical maps without having to "zoom in". Moreover, the mullion size between the LCDs, 13.2 mm vertically and 12.8 mm horizontally, which led to a fill factor (FF) of 92%, is the most significative improvement over the first generation ToMaDi. The FF is defined by a ratio of the total active display area of the 16 LCDs over the global area, which includes those LCDs. This improvement was obtained by the judicious selection of a TFT-LCDs used for laptop computers. Among the different kinds of LCDs available on the market, laptop LCDs are those with the thinnest border around the active display area, as shown in Figure 8. The complete set of ToMaDi MkII characteristics, compared with the ToMaDi first generation ones, are listed in the Table I.

The TFT-LCD used for the design was the LG-Philips LP141XA (Ref. 9). Their main specifications are listed in Appendix B. The main reason of its selection was that there were no other laptop LCDs with compatible analog-to-digital (A/D) interface board

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available on the market. Despite this fact, the LP141XA is a very good TFT-LCD. Its colour rendition, as illustrated in Figure 9, is smaller than that of common CRT (Ref. 10) but sufficient for digitized map visualization. The complete set of LP141XA characteristics, compared with the FPD used in the ToMaDi first generation, are listed in the Table II.

The interface board chosen for the design was the Digital View AC-1024V3. It supports the A/D conversion between the analog video signal sent by the PC and the LVDS digital signal required by the TFT-LCDs (Ref. 11). The AC-1024V3 connection diagram with the LP141XA is illustrated in Figure 10. The 12V DC supply to the 16 AC-1024V3 housed in the MkII rear enclosure is provided by a set of 4 power supply unit ULTRAFLEX UBJ1-JJJJ-ND made by Lambda (Ref. 12). For flexibility purposes, they were grouped together in a separate enclosure. On the computer, four PCI-based MVP-Pro 128 video card, with four video channels each, were used to produce sixteen analog XGA (1024 x 768) video signals. They are made by the Enseo company (formerly known as STB) (Ref. 13). The display drivers provided with these video adapters are very flexible, which allow the users to select display configuration of their choice, such as: 16 x 1, 2 x 8, 3 x 5, 4 x 4, etc. During the year 2000, two more ToMaDi MkII systems have been built for the COP-21 and ISTAR projects undertook at DRDC Valcartier.

4.2 The ToMaDi MkII Touchscreen Capability

The addition of touchscreen capability to the ToMaDi MkII, by putting a modified digital board over the TFT-LCD array, is of great importance in terms of user interaction. The modification involved the replacement of the white writing surface, which is essentially opaque and "passive", by a polycarbonate-made transparent one. This solution was chosen because of the unavailability of large enough transparent high-resolution capacitive or resistive touchscreen devices (the maximum size was around 22" diagonal!). Smart Board (Ref. 14), a Canadian firm, produced a transparent touch sensitive digital board. However, this board was not purchased, for reasons of budget constraints. The digital board selected for the design was Model 201 made by Polyvision (formerly Softboard) and its working principle is based upon IR laser scanning, as shown in Figure 11 (Ref. 15).

The two laser scanners placed in the upper part of the board scan continuously a plane which is parallel and 0.25" apart from the display surface. When a retro-reflective

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tipped wand intersects this surface, its position is computed by triangulation with a resolution of 1 mm and sent through the serial link to the computer. Despite its size, the digital board acts like an ordinary mouse. The driver in the PC makes the geometric correction in real-time in order to place the cursor (usually an arrow) at the right place on the screen. The presence of mullions introduces an error between the pointed location and the cursor location on the mosaic of the screens which never exceeds 9.9 mm [4]. For this reason, the icons and controlling features on the desktop should not be too small. The settings of all visual attributes to avoid too small displayed Graphical User Interface (GUI) features are listed in Table III. These settings can be modified in the Windows NT4 Display Properties control panel. The "wand-based" pointing technique has the advantage that only one person at a time is in control.

5.0 DIFFICULTIES ENCOUNTERED

Between the video card in the PC and the TFT-LCD panel, the interface card that makes the A/D conversion plays a crucial role in the ToMaDi MkII operation. In other words, it is not possible to skip over this component if it is difficult to find a compatible part. That was the case for this project, as previously mentioned. In the electronic display domain, laptop LCDs are used essentially in laptop computers and the others LCD are used in desktop computer monitors. Since a laptop LCD is driven digitally (no A/D conversion) from the laptop main board, the interface board manufacturers produce almost essentially items that are compatible with display monitor LCDs which results in a low availibility of these specialized boards.

When sixteen fragile LCDs are to be placed side by side on a same plane, the mounting surface rigidity is a main concern. Usually, in mechanical designs, rigidity means heavy and lightness means flexible or fragile. To fulfil the rigidity criteria while having a not too heavy display module, a 4' x 4' x 1.5" Goodfellow Ltd. aluminium honeycomb plate was used (Ref. 16). The transparent polycarbonate sheet used to replace the opaque white panel of the digital board has two main functions. It allows to see and protect the fragile LCD array from the wand when used and provides continuous smooth surface when a dragging operation is performed. Unfortunately, the polycarbonate is a matter

4. The absolute maximum position error is 3/4 of a mullion as demonstrated in Figure 13

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with a positive thermal expansion coefficient. Because of the heat from the 16 LCDs, produced by the Cold Cathode Fluorescent Lamp (CCFL), the sheet bends significantly to a point that the operation of the laser scanners are disturbed. To counter this problem, the original design was modified to allow the sheet to expand freely by holding it by the top like a "curtain". The three other sides were held by using expansion slots.

6.0 MILITARY UTILITY ASSESSMENT

The ToMaDi MkII was experimented during three military exercises. First, it was demonstrated at the Joint Warrior Interoperability Demonstration (JWID-00), in July 2000 (Ref. 17). It was deployed at the National Imagery & Mapping Agency, in Bethesda, MD, in a joint Canadian / US demonstration. ToMaDi MkII was used within the "Canadian" cell where the computer material was a contribution of the DND J2Geomatics Department. The main function of this cell was to allow data access to large geographical databases and to display geospatial information on a Web browser. Essentially, the ToMaDi MkII was used to display topographical data, satellite imagery and digital terrain elevation data from Canadian geospatial data warehouse servers through a Web browser (Internet Explorer 5.0). Because of its large display area and high local resolution, the ToMaDi MkII allowed the users to efficiently examine a large geographical area without the need for panning nor scrolling. Moreover, they were able to interact and discuss as a group in front of the display about the current tactical situation. Secondly, in July 2001, the three ToMaDi MkII available have been deployed in Ottawa (2 units) and Winnipeg (1 unit) for the JWID-01 exercise. They have been used in the AFCCIS and the COP demonstration systems.

Thirdly, one ToMaDi MkII was used in the Land Intelligence and Electronic Warfare Automation (LIEWA) experiment 1A, in August 2000. The main objective of this experiment was to test the ASIP software developed at DRDC Valcartier. More precisely, the ToMaDi MkII was used to assess the value of ASIP's collaborative work sharing capability versus the use of a traditional hierarchical architecture. For two weeks, twenty staff officers played a land tactical military scenario. Twice a day, the intelligence officer (G2) of the brigade headquarters used ToMaDi MkII to debrief his understanding of the current situation. It allowed several staff officers to discuss about the global situation or a specific aspect of the tactical situation. The touchscreen capability was frequently used to control the

displayed information and select the area of interest on the map. The presence of mullions was not considered by the officers as a major visual disruption of the graphical information. An example of the ASIP workspace is shown in Figure 12.

7.0 LESSONS LEARNED FROM THE USE OF ToMaDi MkII

The use of ToMaDi MkII during the three above-mentioned exercises led to some display configurations and "usage" rules of such a display. A software package intended to be used on ToMaDi MkII should have a specifically designed or modified GUI to take the advantages of ToMaDi MkII. The following rules illustrate this point:

1. A small window (less than 1024 x 768 pixels) should be displayed entirely in one TFT-LCD to avoid this window being split into two or four parts. This is also true for the textual information which is difficult to read when segmented into two or more parts.
2. It is better to display small windows on any of the 12 uppermost TFT-LCDs. The lower TFT-LCDs row is not well perceived by people working near ToMaDi MkII's screen.
3. The best area of the overall device is constituted with the 2 x 2 array of TFT-LCDs in the middle of the screen.
4. The GUI controls (e.g. buttons) should be large enough (about 64 x 64 pixels) and sufficiently spaced from each other to click or double-click on it with ease, without activating surrounding GUI controls. The output GUIs should be large enough to display significantly information to its users. The lines of text should be large enough and sufficiently spaced from each other.
5. Because the double-click operation on ToMaDi MkII is very different from that made by using a mouse, the double-click speed should be slow enough and tolerance for the second click in the order of 32 pixels.
6. The Appearance setting in the "Display Properties" should be set in order to adjust the Windows features to a size large enough to be used with ease on ToMaDi MkII. All those appearance settings can be advantageously saved as a specific scheme.
7. The pull-down and the pull-up menus (like the "Start" menu in the Windows envi-

ronment) should be designed in order to be controlled by "click and drag" motion. This way of controlling the workspace is less sensitive to the inherent "touch-screen" inaccuracy.

8. A map visualization window should have an easy-to-use scrolling control (up-down and left-right) in order to move easily the map to an area where key information is not obstructed by a mullion.

8.0 SUGGESTION ENHANCEMENTS AND FUTURE DIRECTION

Although ToMaDi MkII has proven its value for C&C applications, some enhancement should be considered for the possible next phases of the project. The first one would be to get rid of the imprecision between the wand position when it touches the screen and the localization of the cursor on the screen. This is caused by the difference between the touchscreen surface, which is continuous, and the active display surface which is divided by 3 horizontal and 3 vertical mullions. The SB Projection software package, used with the digital board to control the cursor position, has an alignment grid to make the appropriate correspondence between the displayed desktop and the laser scanned surface. This allows a "zero position error" at the periphery of the display surface, but the error fluctuate elsewhere as the wand location moves away from the surround and traverses mullions. Taking into account the horizontal case, "L" is the distance between the leftmost displayed column and the rightmost displayed column. The position error is defined as the distance between the wand location and the cursor location and is positive or negative if the cursor is at the left or the right of the wand, respectively. The horizontal cursor positioning error expressed in horizontal mullions with respect to the horizontal position of the wand is shown in Figure 13. The same demonstration can be done for the vertical position error. Knowing the absolute error and the pixel density of the LCDs, it could be possible to apply a correction offset in order to set to zero the error when the wand is not over a mullion, as shown by the dashed line in Figure 13.

Despite the fact that the digital board did a very good job by controlling precisely the cursor position, it is relatively heavy (28 kg) and increases significantly the overall dimensions and depth of ToMaDi MkII. For this reason, it should preferable to use for the next design a similar optical based positioning system made by E-Beam (Ref. 18). It is lightweight, relatively cheap compared with the Softboard and sufficiently compact to be

integrated directly onto the TFT-LCD tiled display. Moreover, if a large enough capacitive or resistive transparent touchscreen device is available, like those currently made by 3M (formerly MicroTouch) (Ref. 19), it could constitute an attractive "solid-state" pointing device solution.

Another improvement that has already been implemented in the last ToMaDi MkII display deals with the orientation of the TFT-LCDs. It was installed and tested in the DRDC Valcartier's mobile command post laboratory that is used to experiment and demonstrate advanced C&C hardware and software, as shown in Figure 14. The TFT-LCDs used for the ToMaDi MkII are not symmetric in terms of vertical (top-down) viewing angle. They provide a vertical viewing angle of 40°, as previously mentioned, but with a 10° upper bias (12:00 o'clock viewing position). Taking into account the usual users' height who have their eyes facing the middle of the screen, the two bottom rows of the ToMaDi MkII LCDs mosaic have been placed upwards, so that their 10° viewing angle is oriented upwards. The top two rows have been oriented downwards, with a 180° image rotation done in the A/D interface board. By doing so, the two upper rows of LCDs have a much better contrast for most users even in confined space.

The laptop LCD domain is in constant evolution. The features of the produced items are increasing almost on a monthly basis. For instance, the Toshiba LCD Division is now producing (Q4/2001) the LTM15C162S TFT-LCD, which is a 15" diagonal laptop LCD with a total resolution of 1600 x 1200. This corresponds to a local resolution of 134 ppi and horizontal and vertical mullions of 11.8 and 13.5 mm, respectively. This component or a similar one could lead to a ToMaDi having a 60" diagonal display with a total resolution of 6400 x 4800, if the 4 x 4 configuration is chosen. This could provide a larger workspace for the applications and better detail rendition for graphical information in comparison with the current ToMaDi MkII version. Of course, depending on specific needs, the size, resolution of each LCD and global configuration (4 x 4, 4 x 5, 5 x 5, 3 x 5, etc.) would be judiciously chosen.

To enhance displayed image quality, many other improvements could be made for the next prototype. Instead of using the analog Video Graphics Array (VGA) signal format between the PC and the LCD interface, it could be better to use a digital signal as the digital visual interface (DVI) or the digital flat panel (DFP) standards, proposed by the Digital Display Working Group (Ref. 20) and the Video Electronics Standards Association (Ref. 21), respectively. A digital video signal provides better image clarity and simpler interface

board. The LCD back light would be made by using a white LED array, which is more robust, efficient, lasts longer and necessitates much lower supply voltage than a CCFL unit used in TFT-LCDs. Finally, to increase the perceived contrast ratio of the display screen, the use of an anti-glare or anti-reflection film placed on the touchscreen surface would be of great interest if a roll large enough to meet our needs is available.

9.0 CONCLUSION

The development of ToMaDi MkII has been an interesting engineering challenge. Apart for the frame that holds all the components, ToMaDi MkII has been totally built from COTS hardware and software components, which have been carefully selected. The design of ToMaDi MkII was made to provide a large high-resoluted flat panel, to minimize total weight, still providing sufficient robustness, and to optimize the ease of interaction for the user.

From the experimentation point of view, ToMaDi MkII has proven its value for C&C applications, during the three military exercises. Its large display area is particularly useful to display digital geospatial data covering large geographical areas. It made it possible for staff officers to interact efficiently together with the display. Staff officers did appreciate its large touchscreen surface to debrief other people and share their understanding of the military situation depicted in the exercise.

Although ToMaDi MkII has been applied so far to a military context, it has generated strong interest in other application domains, such as search and rescue and police command and control systems. As a matter of fact, its is suitable for any application where monitoring a large area is necessary. This could include civilian protection, management of hydro electrical networks over a state or province or tracking a fleet of transportation trucks.

Three prototypes of ToMaDi Mk II have been developed at Defence R&D Canada – Valcartier so far. In order to facilitate further exploitation and fielding of the ToMaDi technology, DRDC Valcartier is looking forward to license its technology to a commercial partner.

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10.0 ACKNOWLEDGEMENTS

The author wishes to express his gratitude to DRDC Valcartier's Prototype Section, including Dr. Guy Vézina, Messrs. Jean-Claude Drolet, Denis Gouin, Gaétan Thibault, Gaétan Labrecque and Maj. Michel Gareau for their assistance and guidance during the ToMaDi MkII development.

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11.0 REFERENCES

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10. http://www.videoessentials.com/jkp_facts.htm
11. http://www.digitalview.com/products/controllers/
12. http://www.lambdapower.com/products/ultra-flex-ac.htm
13. http://www.enseo.com/mvp.html
14. http://www.smarttech.com/products/rearprojection/index.asp
15. http://www.softboard.com/products/200series.html
16. http://www.goodfellow.com/
17. http://www.jwid.js.mil/
18. http://www.e-beam.com/
19. http://www.3m.com/3MTouchSystems/
20. http://www.ddwg.org/
21. http://www.vesa.org/dfplink.html

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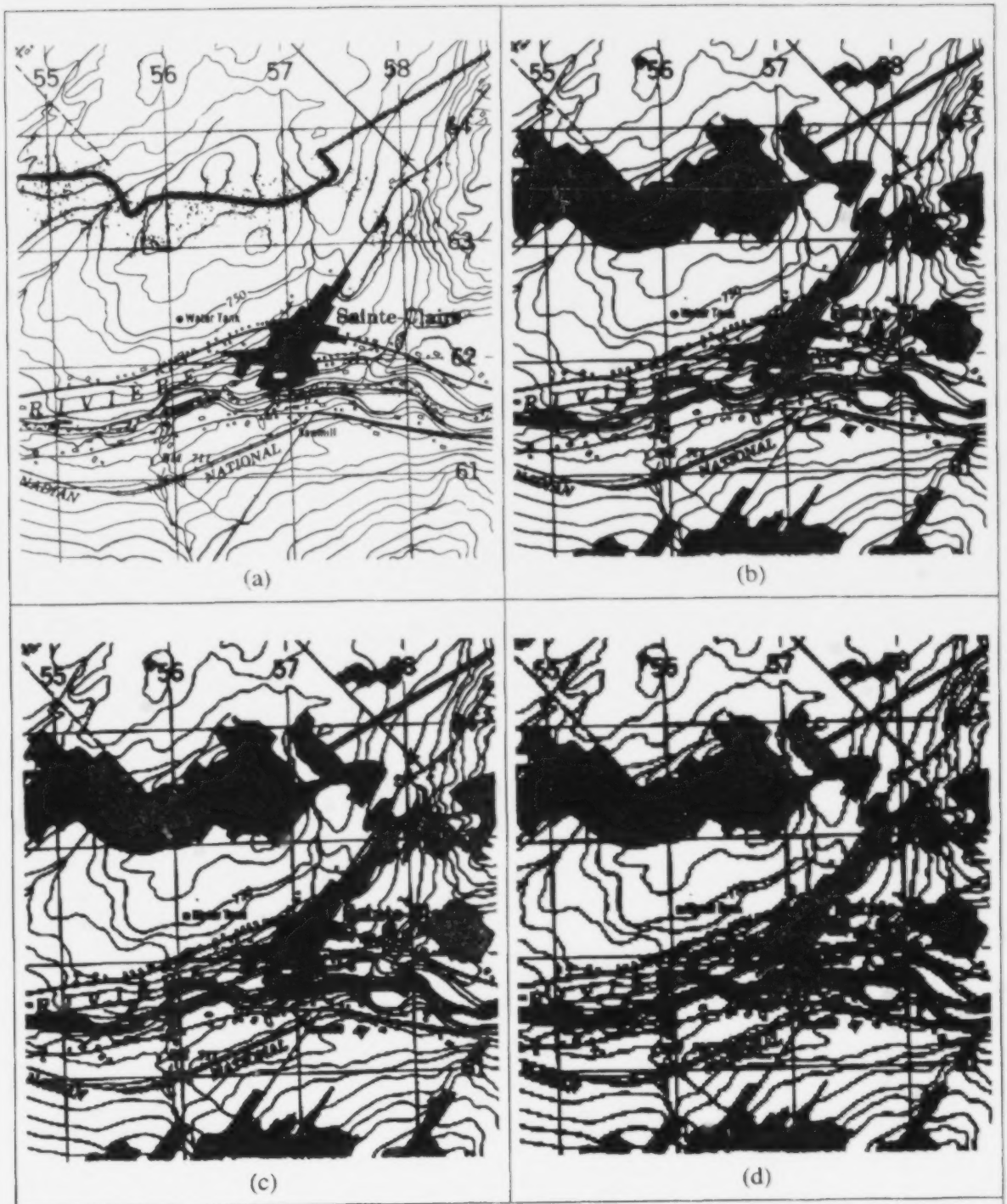

FIGURE 1 - Portion of a digitized 1:50 k topographical maps displayed at different resolution, 300 dpi (a), 100 dpi (b), 75 dpi (c) and 50 dpi (d)

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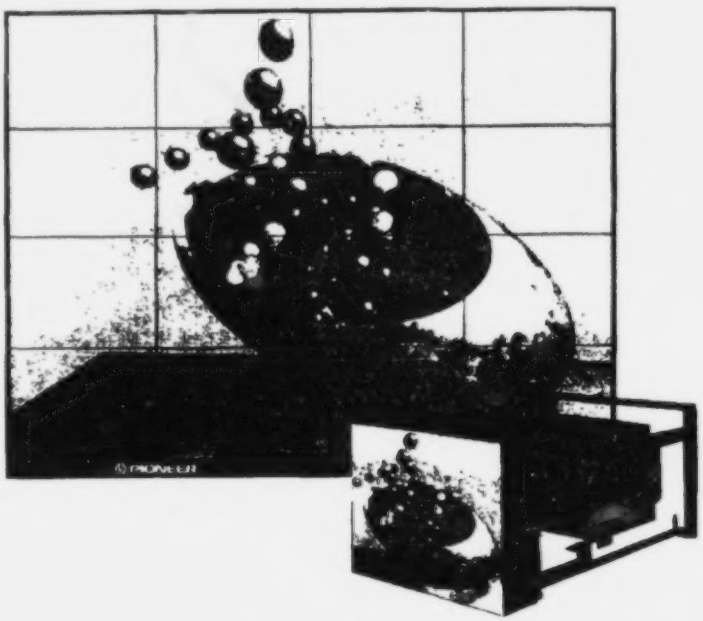
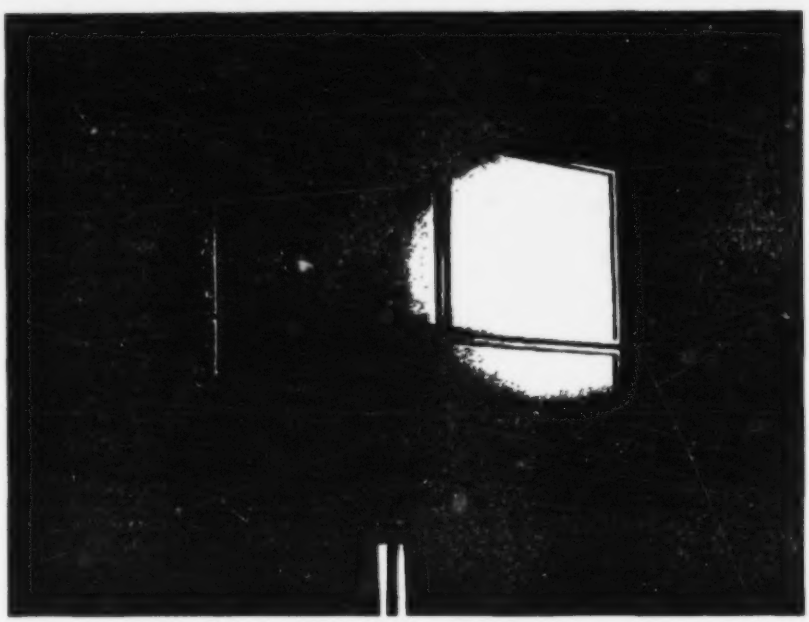
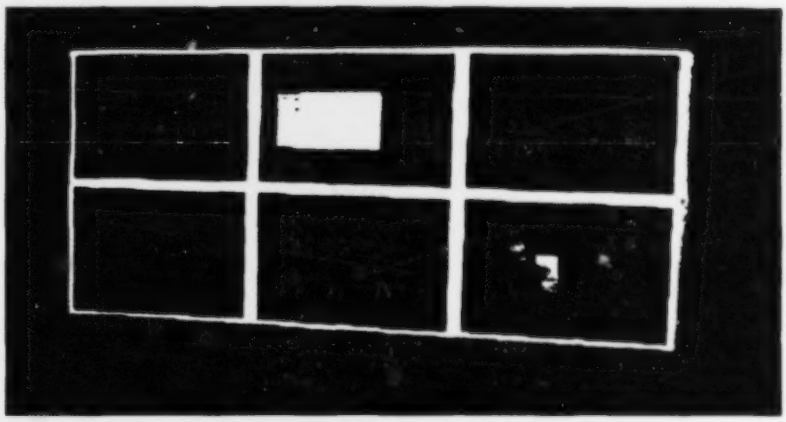


(a)



(b)

FIGURE 2 - Examples of large tiled multi-display systems made by Pioneer Corp. (a) and National Display Systems Inc. (b)



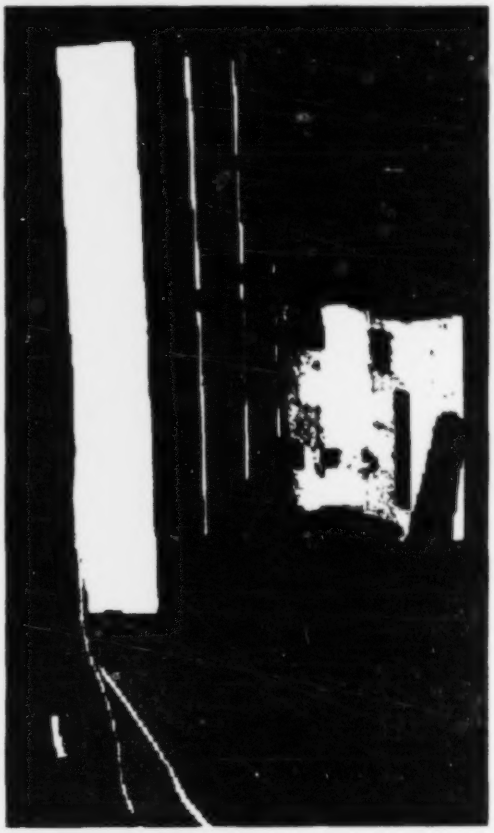
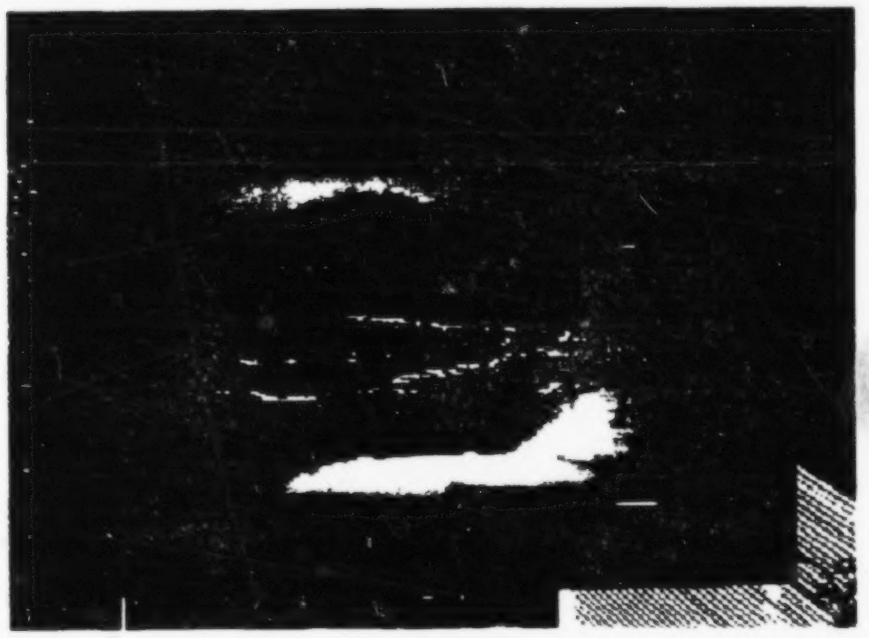
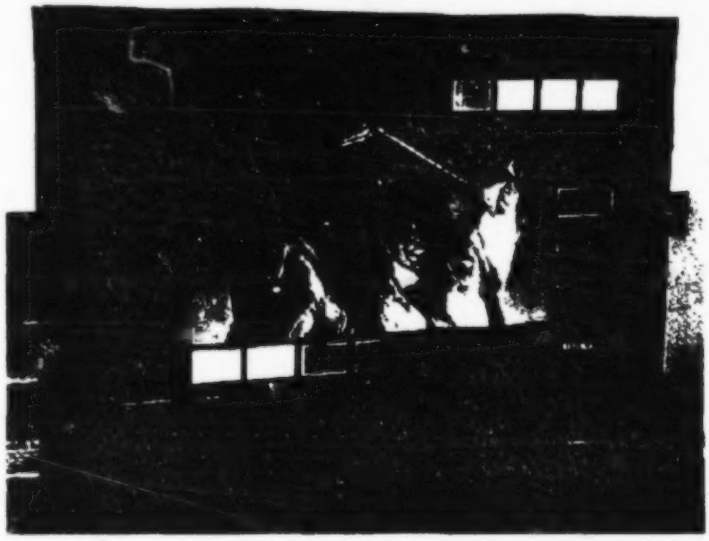


FIGURE 3 - Examples of large tiled multi-display system made by General Dynamics, Communication Systems Division



(a)



(b)

FIGURE 4 - Examples of two large seamless tiled multi-display systems made by Rainbow Displays Inc. having a 2x2 (a) and a 1x3 (b) configuration

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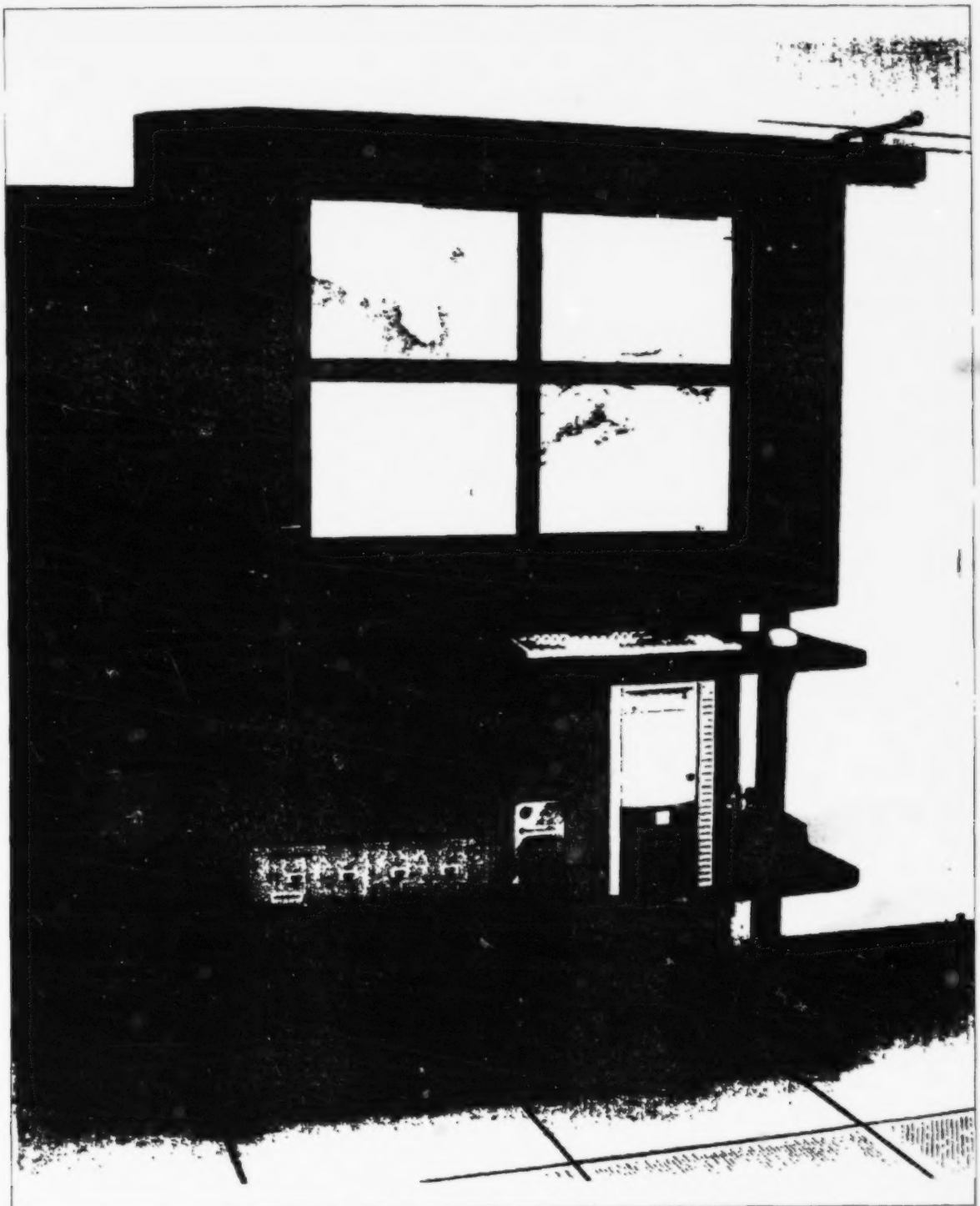
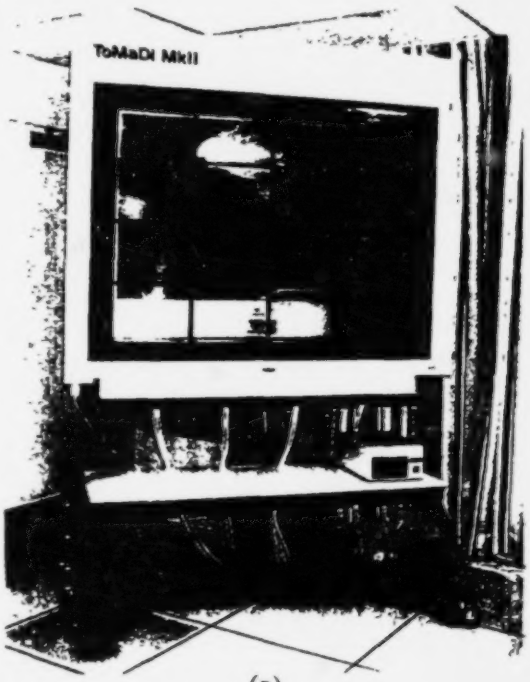
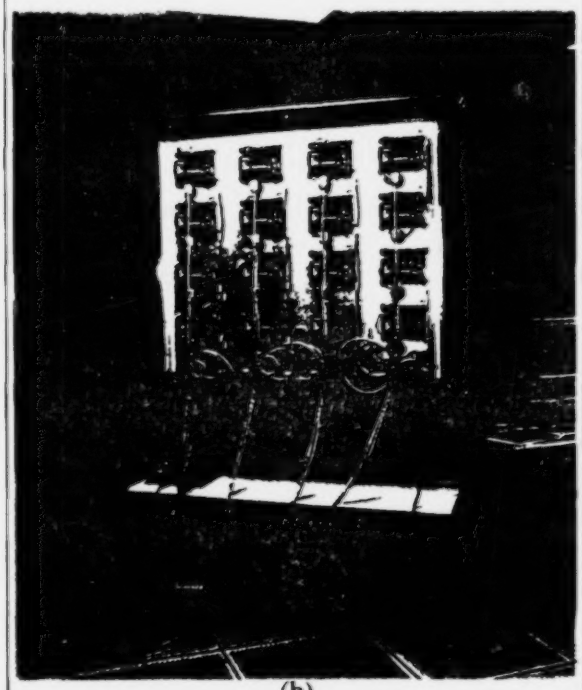


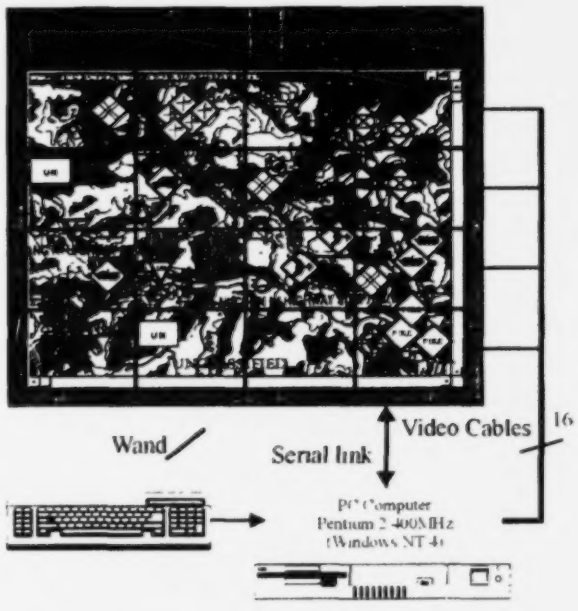
FIGURE 5 - The first generation ToMaDi prototype



(a)



(b)



(c)

FIGURE 6 - The ToMaDi MkII front view (a), rear view (b) and its system diagram (c)

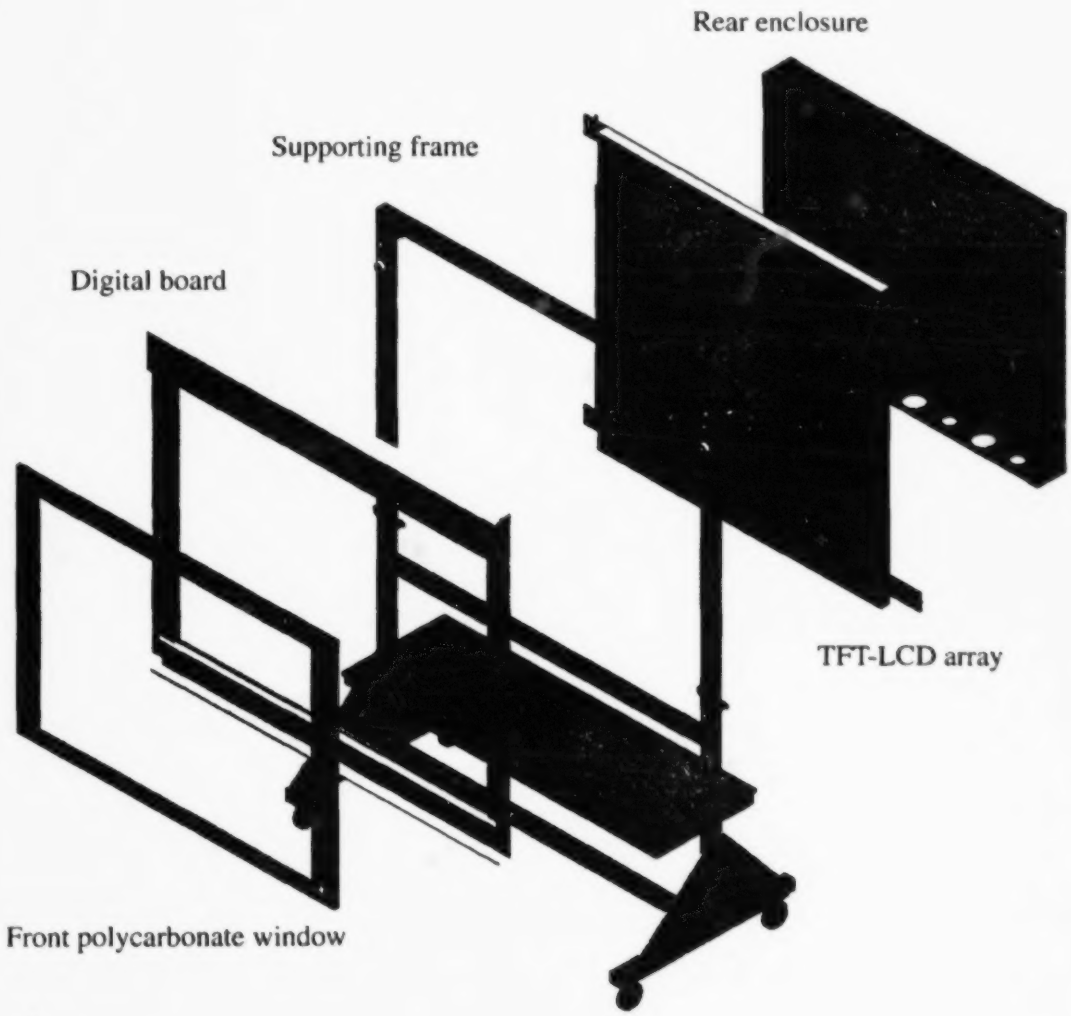


FIGURE 7 - ToMaDi MkII main parts designation

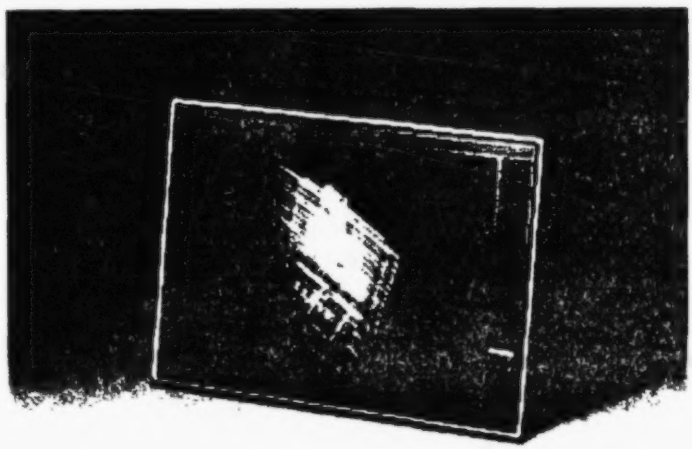


image courtesy of NEC Corp
Note This LCD is very similar to the LP141XA made by LG.Philips

(a)

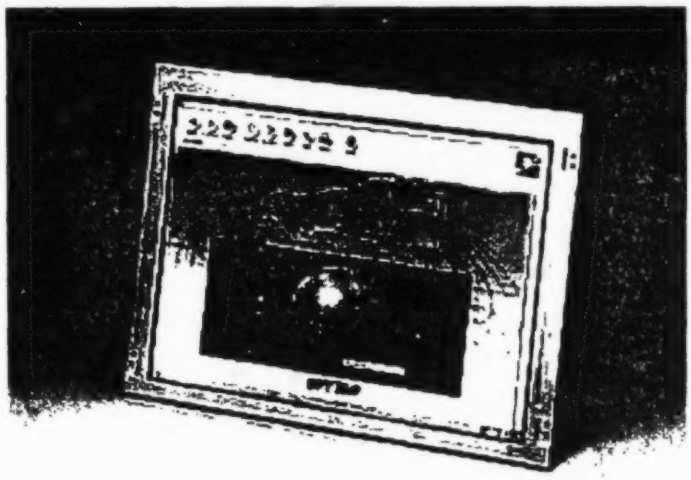


image courtesy of NEC Corp.

(b)

FIGURE 8 - Examples of a 14.1" laptop LCD (a) and a 12" display monitor LCD (b)

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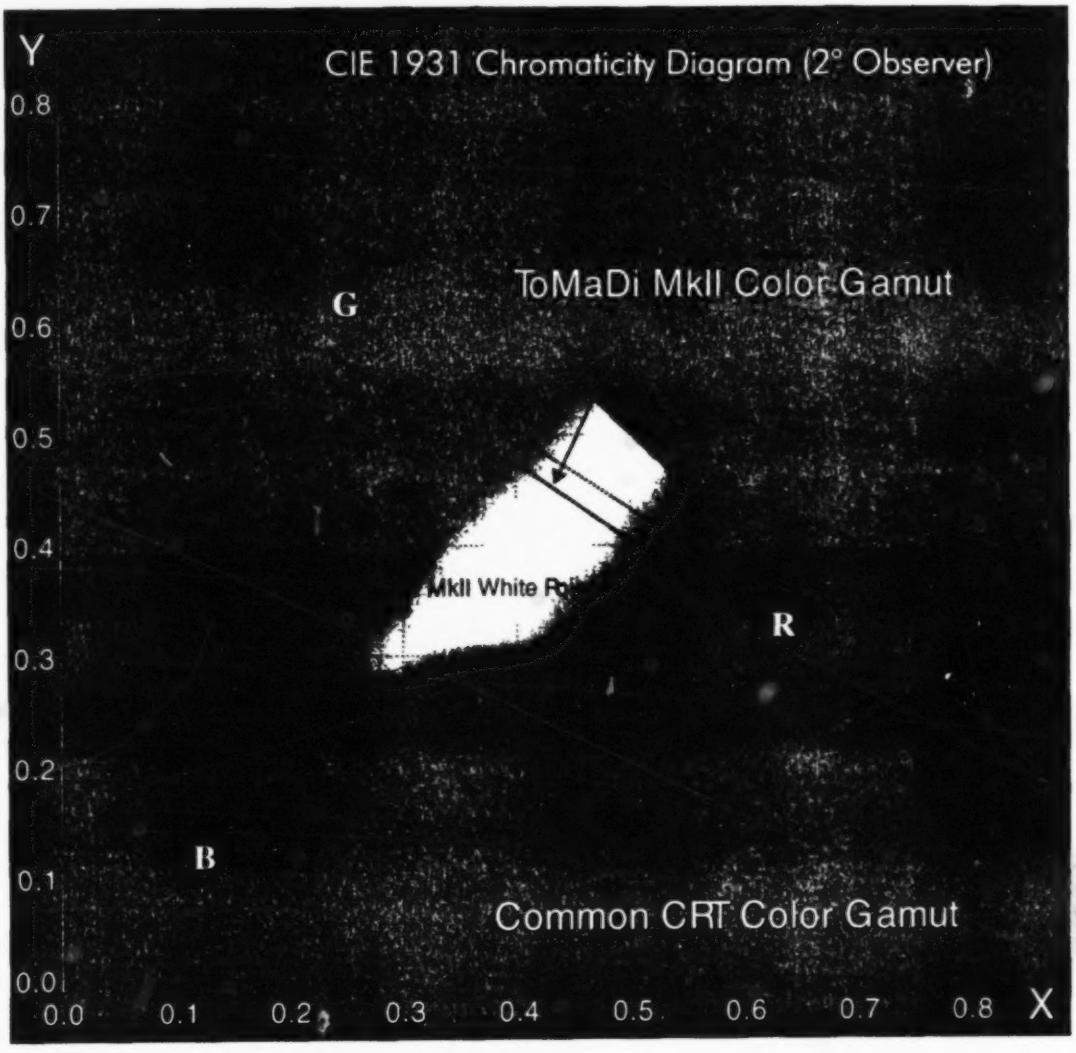


- Solid Line Triangle -	- Dashed Line Triangle -
LP141XA TFT-LCD color gamut coordinates: Red X=0.572 Y=0.350 Green X=0.297 Y=0 549 Blue: X=0 152 Y=0.140	Common CRT color gamut coordinates (Ref 10): Red: X=0.628 Y=0.346 Green: X=0 268 Y=0 588 Blue: X=0.150 Y=0 070

FIGURE 9 - LP141XA and common CRT colour caracteristics

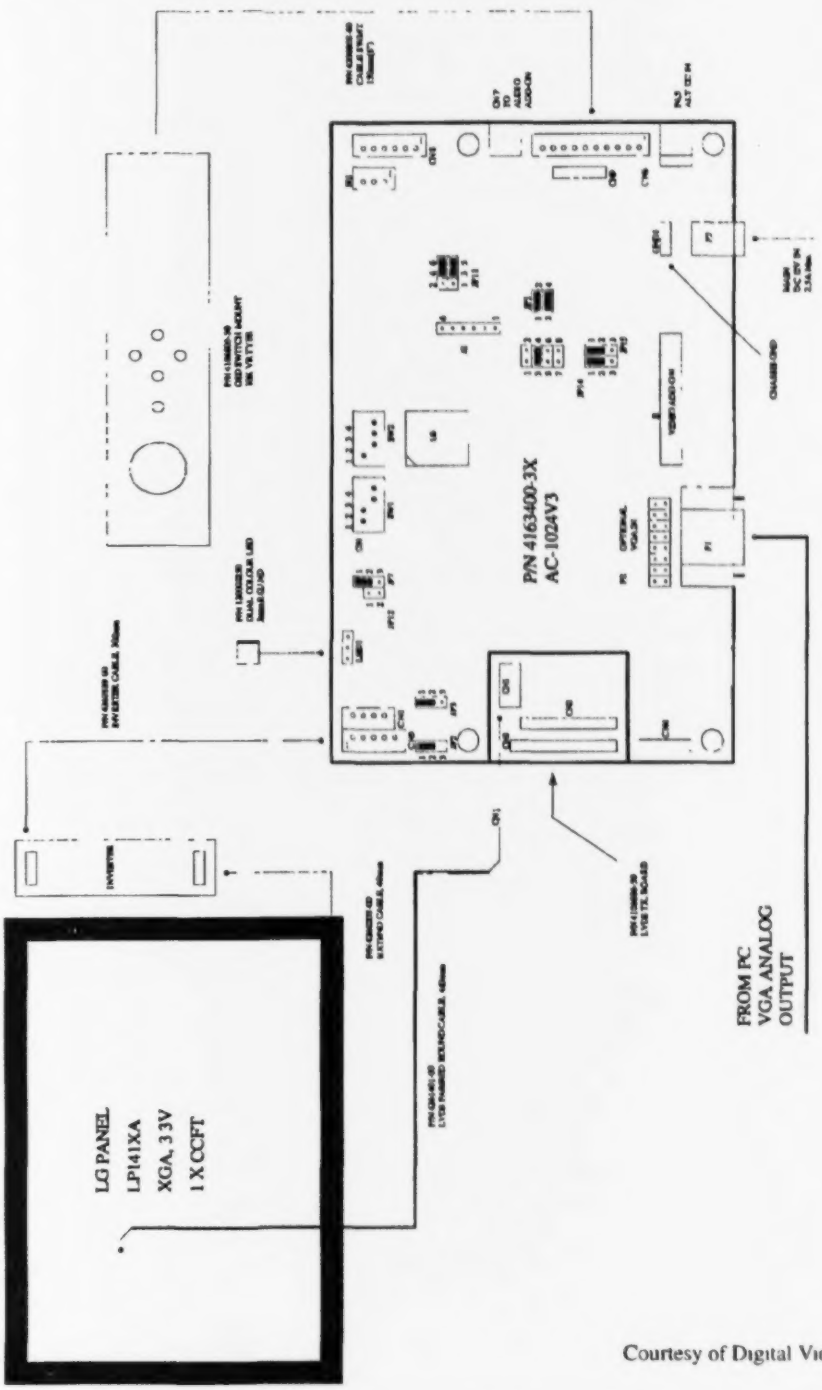
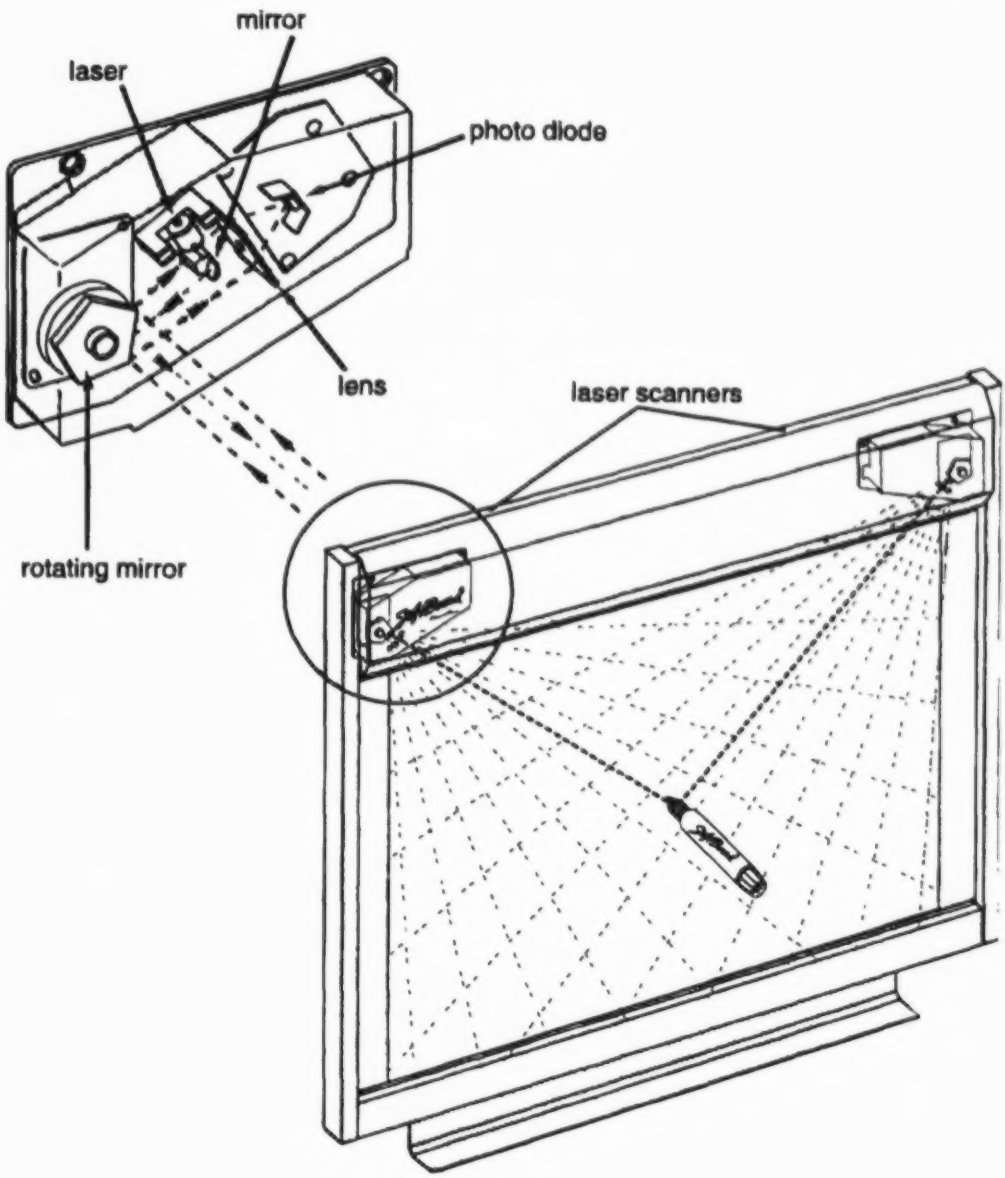


FIGURE 10 - AC-1024V3 interface connection diagram



Courtesy of Polyvision Corp

FIGURE 11 - Softboard digital board principle of operation

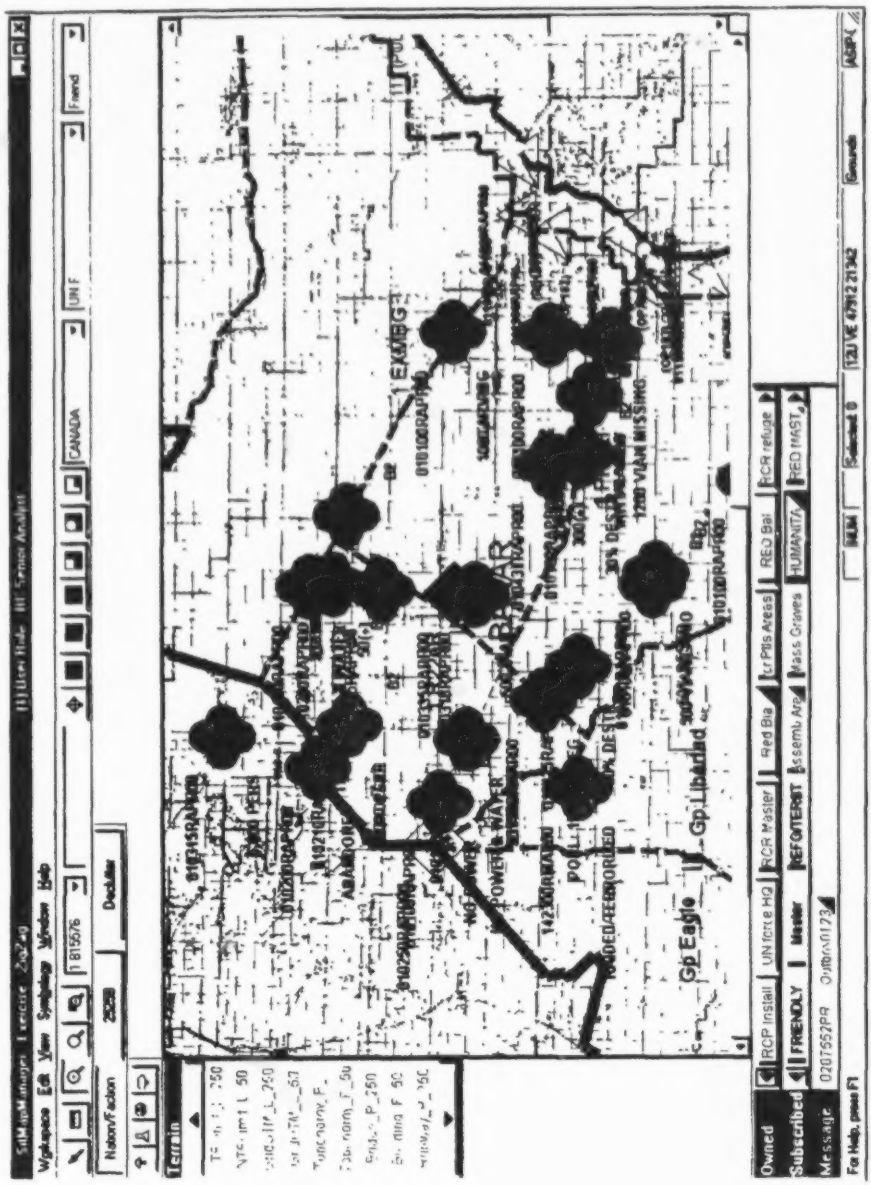


FIGURE 12 - ASIP 1.2 Workspace example

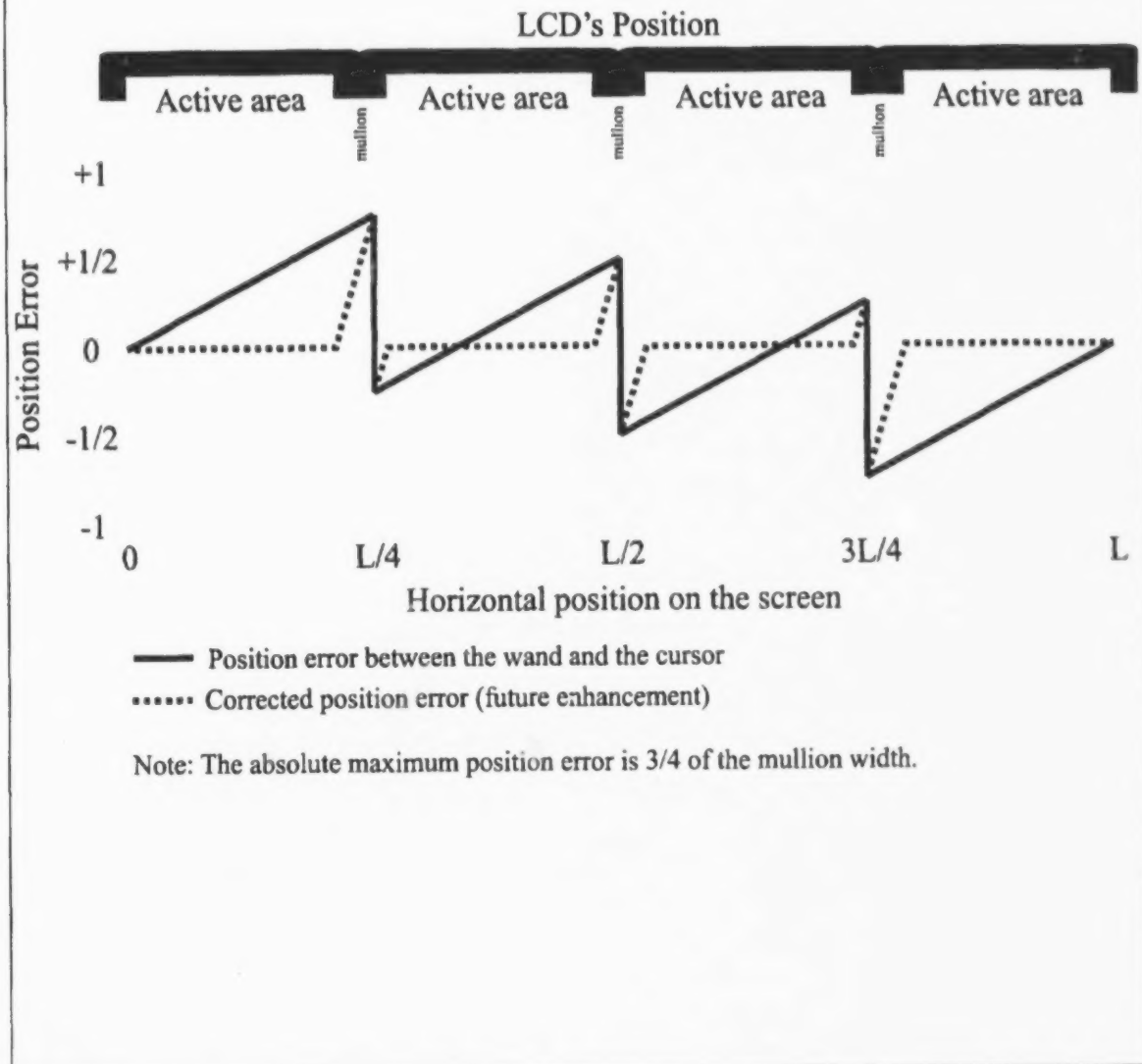


FIGURE 13 - Horizontal cursor position error

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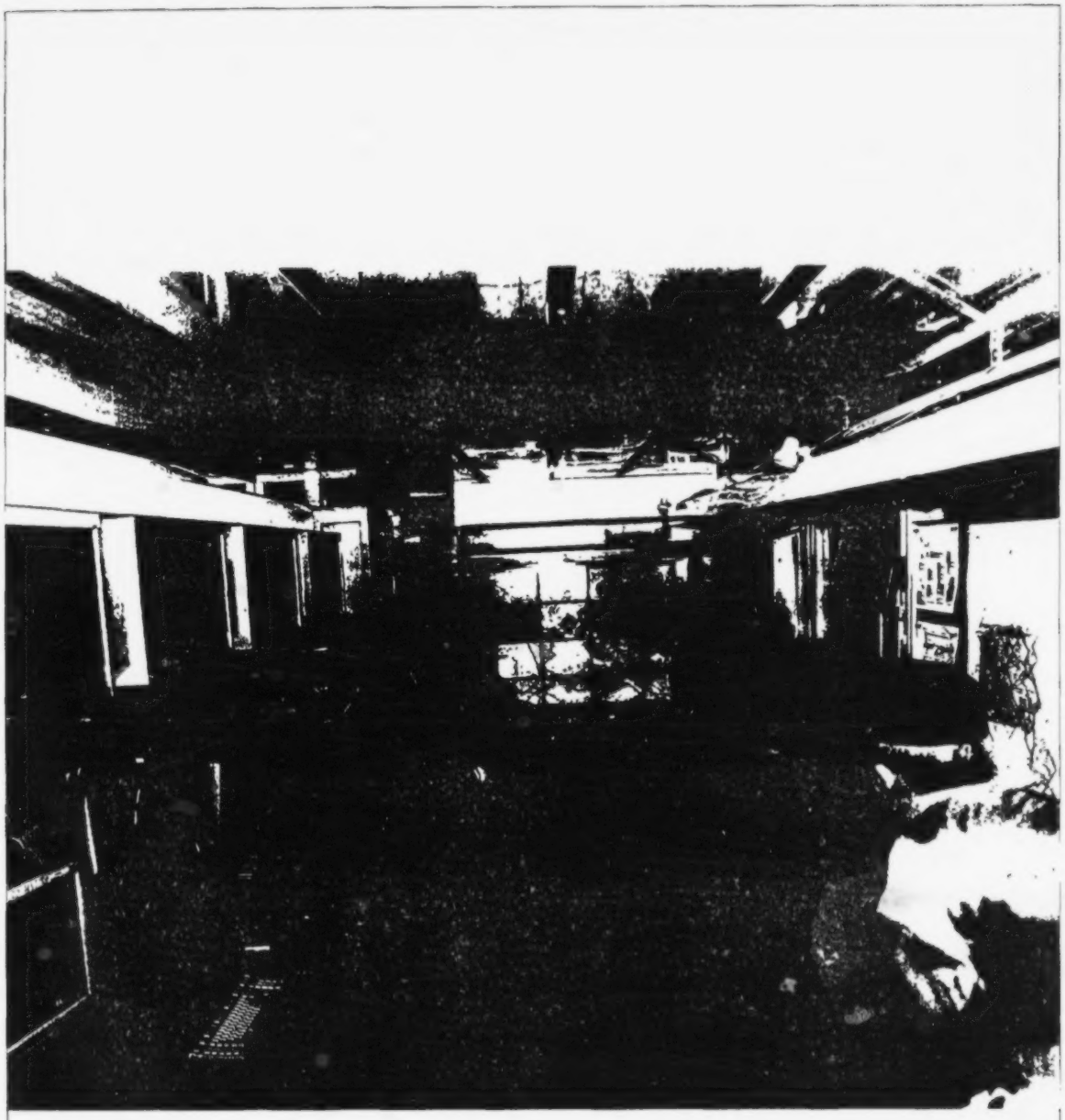

FIGURE 14 - DRDC Valcartier's mobile C&C laboratory

TABLE I

ToMaDi MkII vs. ToMaDi (first generation) Characteristics

Features	ToMaDi MkII	ToMaDi
Mosaic display disposition	4 x 4	2 x 2
Total resolution	4096 x 3072	1280 x 960
Effective display size (diagonal)	56"	42"
Effective display size (horiz. x vert.)	45" x 34"	33" x 25"
Mullion size (horiz. x vert.)	13mm x 13mm	50mm x 46mm
Visual fill factor	92%	88%
Video signal	16 x Analog VGA, 60Hz	4 x Analog VGA, 60Hz
Touchscreen	Yes	No
Touchscreen resolution	1mm	W/O
Total weight (including frame)	~120 kg	~180 kg
External dimention (including frame) (W x H x D)	59" x 88" x 31"	61" x 80" x 32"
PC platform	COMPAC 2X Pentium III 550MHz	DELL 2X Pentium Pro 200MHz
Operating System	Windows NT4	Windows NT4
Video interface Mfg.	Enseo	Colorgraphic
Total power consumption	~500 W	~1000 W
System made as of 12/2001	3	1

TABLE II

Comparison of FPD used for ToMaDi MkII vs. ToMaDi (first generation)

Parameter	ToMaDi MkII	ToMaDi
Display Mfg.	LG.Philips	Fujitsu
Display model	LP141XA	FPF21C8060UA-92
Display technology used	TFT-LCD	AC Plasma
Panel resolution	XGA 1024x768	VGA 640x480
Colour Capacity	262144 (18 bits)	262144 (18 bits)
Active Display Size (diag.)	14.1"	21"
Aspact ratio	4:3	4:3
Active Display Size (horiz. x vert.)	298mm x 227mm	423mm x 316mm
Pixel density	91ppi	38.5ppi
Pixel type	RGB stripe	RGB stripe
Brightness	120 cd/m^2	120 cd/m^2
Contrast Ratio	250:1	60:1
Viewing angle (horiz. x vert.)	90° x 40°	140° x 140°
Mean response time	25ms	0.01ms
Signal interface	LVDS	TTL
Operating temperature	0 to 50°C	0 to 45°C
Weight	0,59kg	5kg
Panel life span	10 000 hrs[a]	10 000 hrs

a. This is the life span of the replacable CCFL included in the panel. The LCD panel itself may last indefinitely.

TABLE III

Windows NT4 appearance settings for ToMaDi MkII

Item	Size	Colour	Font	Size	Colour	Bold
3D Objects	-	Light Grey	-	-	Black	-
Active Title Bar	78	Dark Blue	MS Sans Serif	24	White	Yes
Active Window Border	2	Light Grey	-	-	-	-
Application Back-ground	-	Dark Grey	-	-	-	-
Caption Buttons	78	-	-	-	-	-
Desktop	-	Blue-Gre en	-	-	-	-
Icon	72	-	MS Sans Serif	24	-	-
Icon Spacing (Horizontal)	32	-	-	-	-	-
Icon Spacing (Vertical)	64	-	-	-	-	-
Inactive Title Bar	78	Dark Grey	MS Sans Serif	24	Light Grey	Yes
Inactive Window Border	2	Light Grey	-	-	-	-
Menu	78	Light Grey	MS Sans Serif	24	Black	-
Message Box	-	-	MS Sans Serif	24	Black	-
Palette Title	60	-	MS Sans Serif	24	-	Yes
Scrollbar	32	-	-	-	-	-

TABLE III

Windows NT4 appearance settings for ToMaDi MkII

Item	Size	Colour	Font	Size	Colour	Bold
Selected Items	78	Dark Blue	MS Sans Serif	24	White	-
ToolTip	-	Beige	MS Sans Serif	24	Black	-
Window	-	White	-	-	Black	-

APPENDIX A

ToMaDi MkII Principal Assembly Drawings

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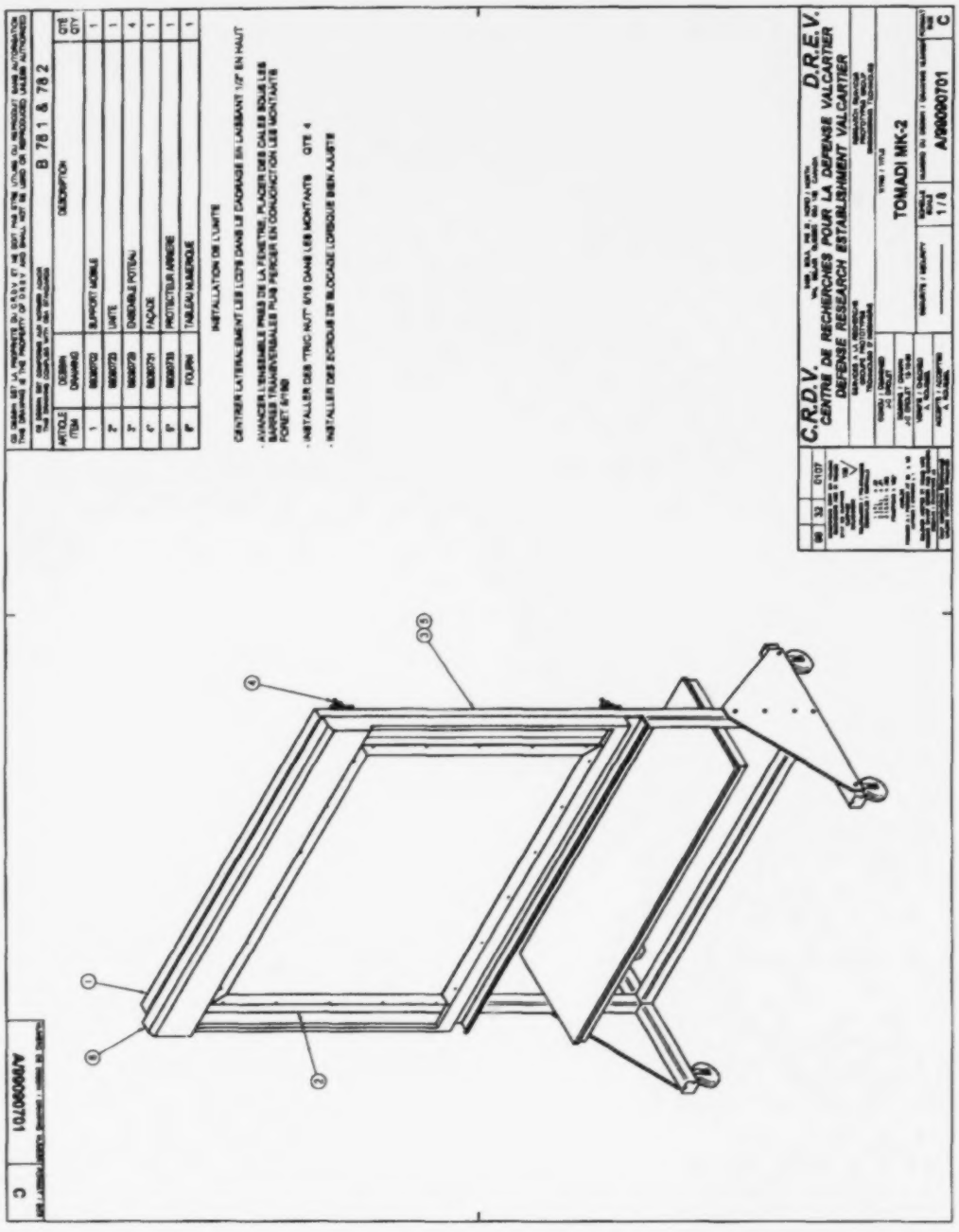

FIGURE A1 - ToMaDi MkII global view

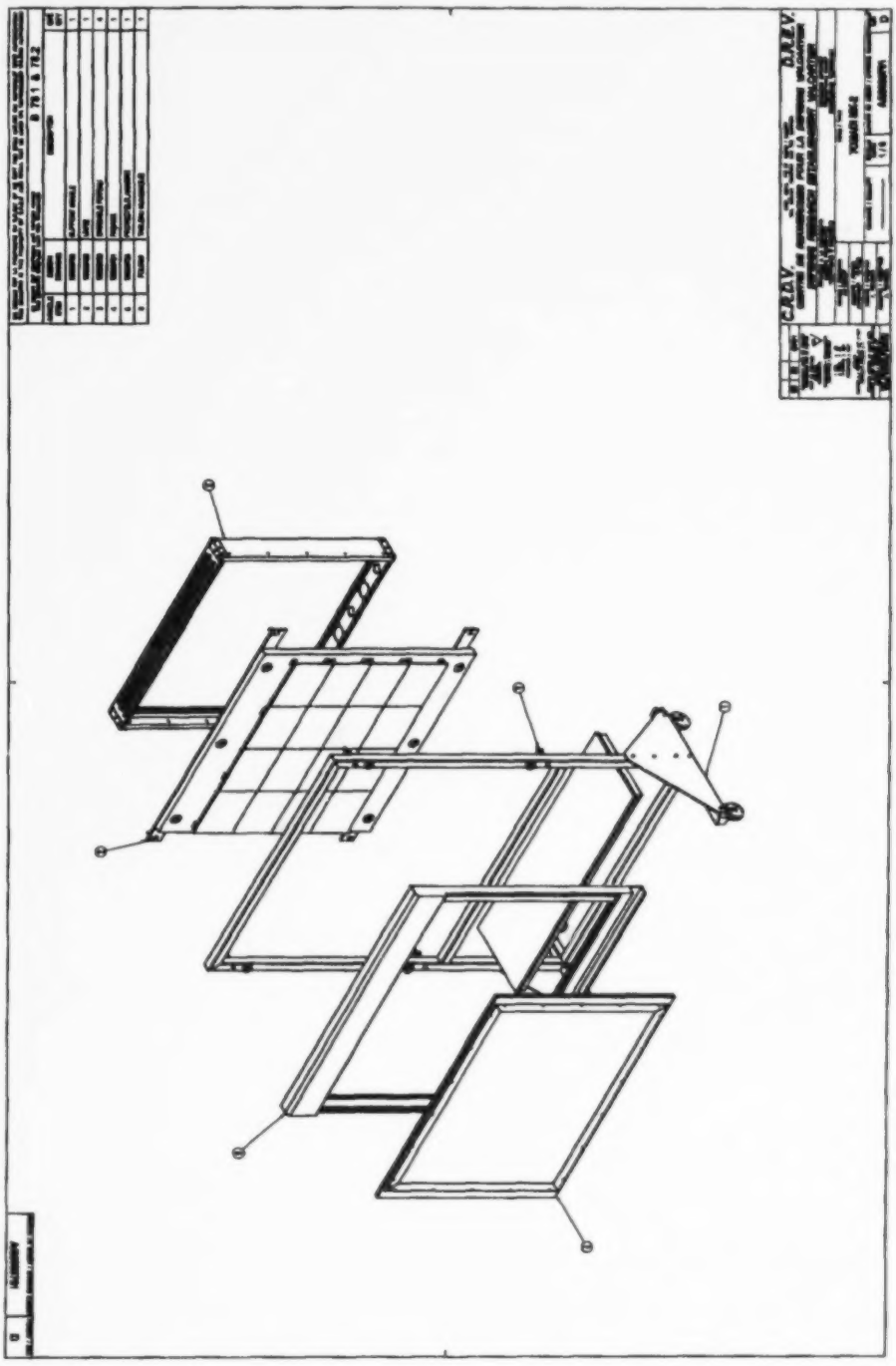

FIGURE A2 - ToMaDi MkII exploded view

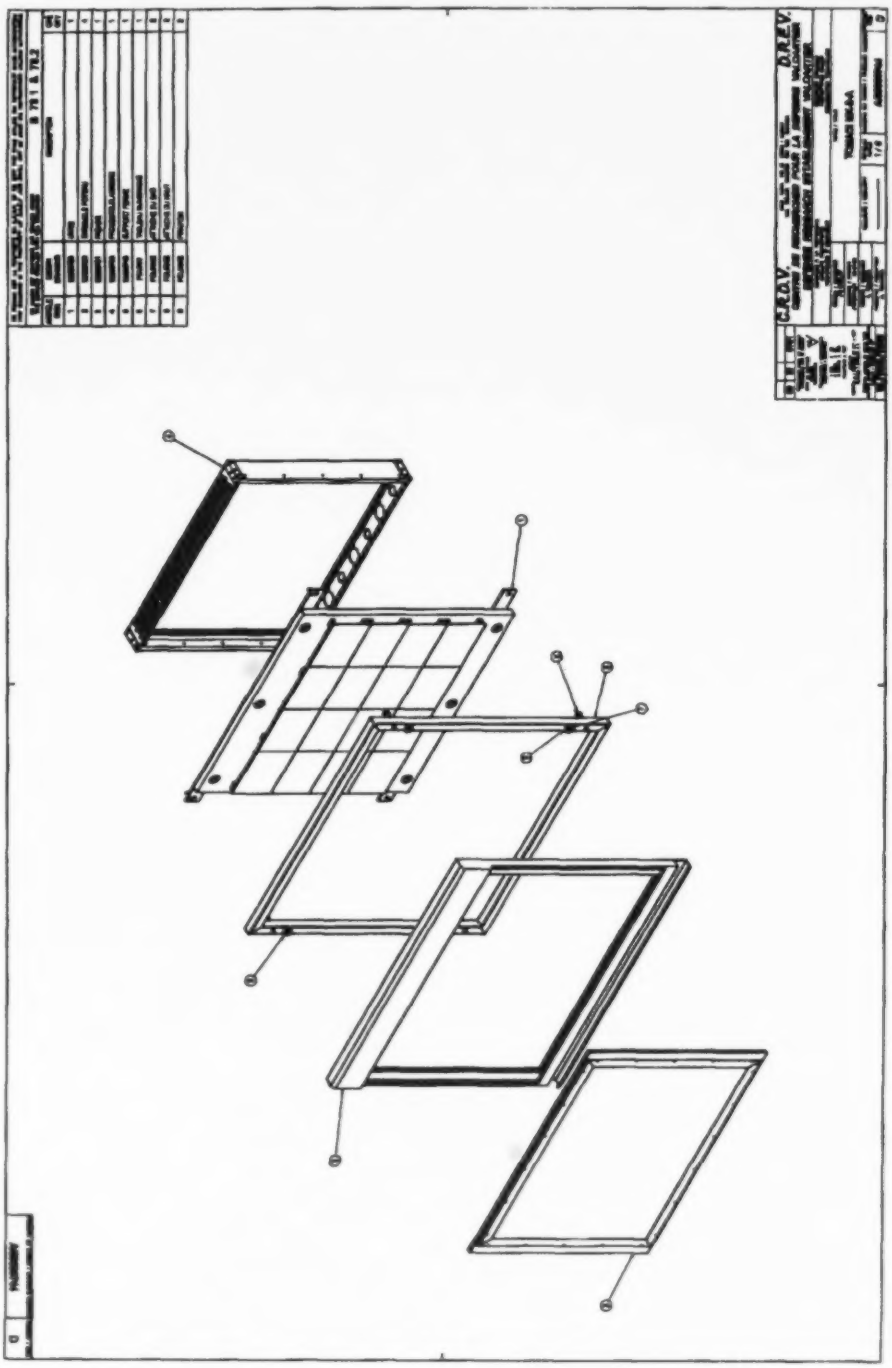

FIGURE A3 - ToMaDi MkII exploded display unit

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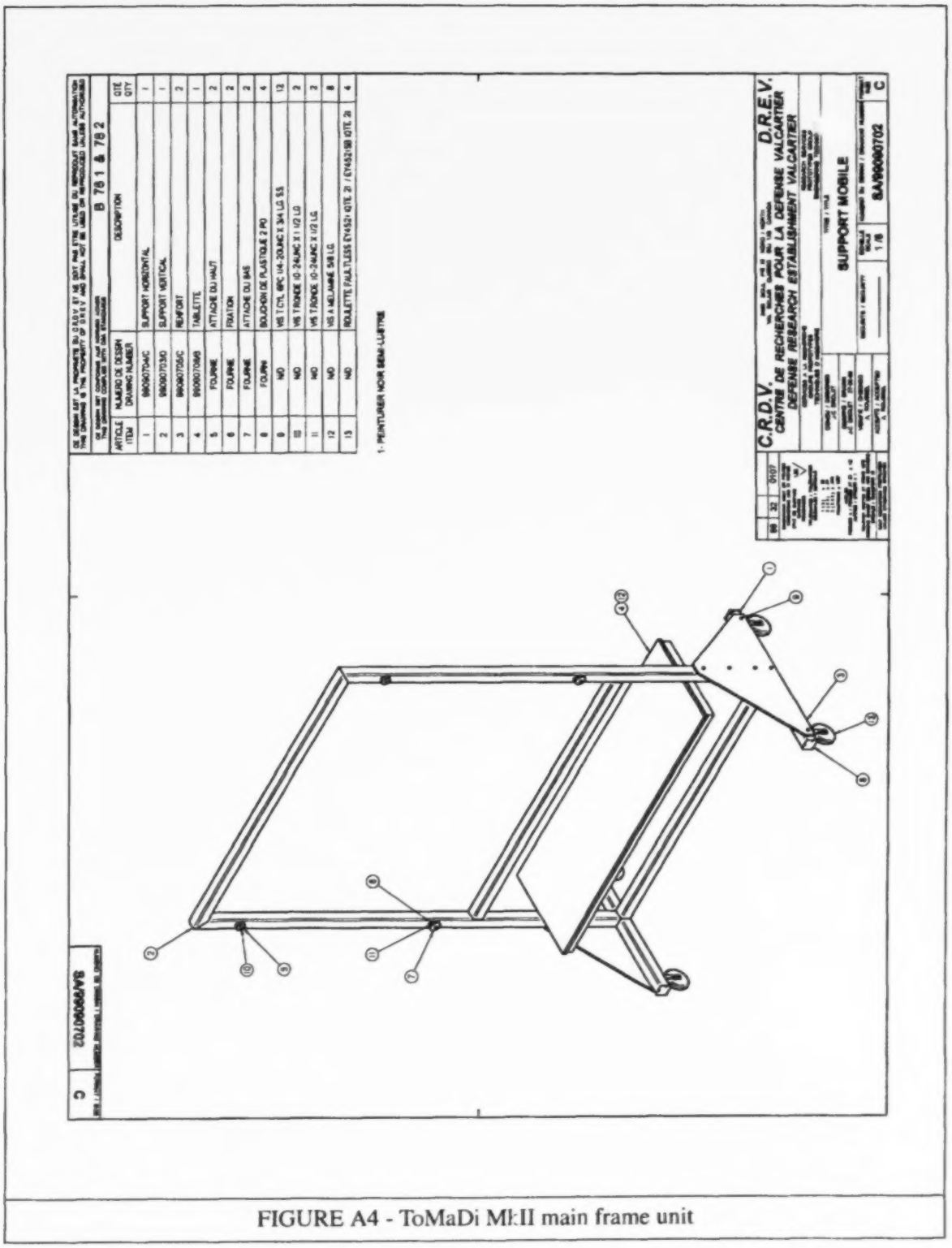

FIGURE A4 - ToMaDi MkII main frame unit

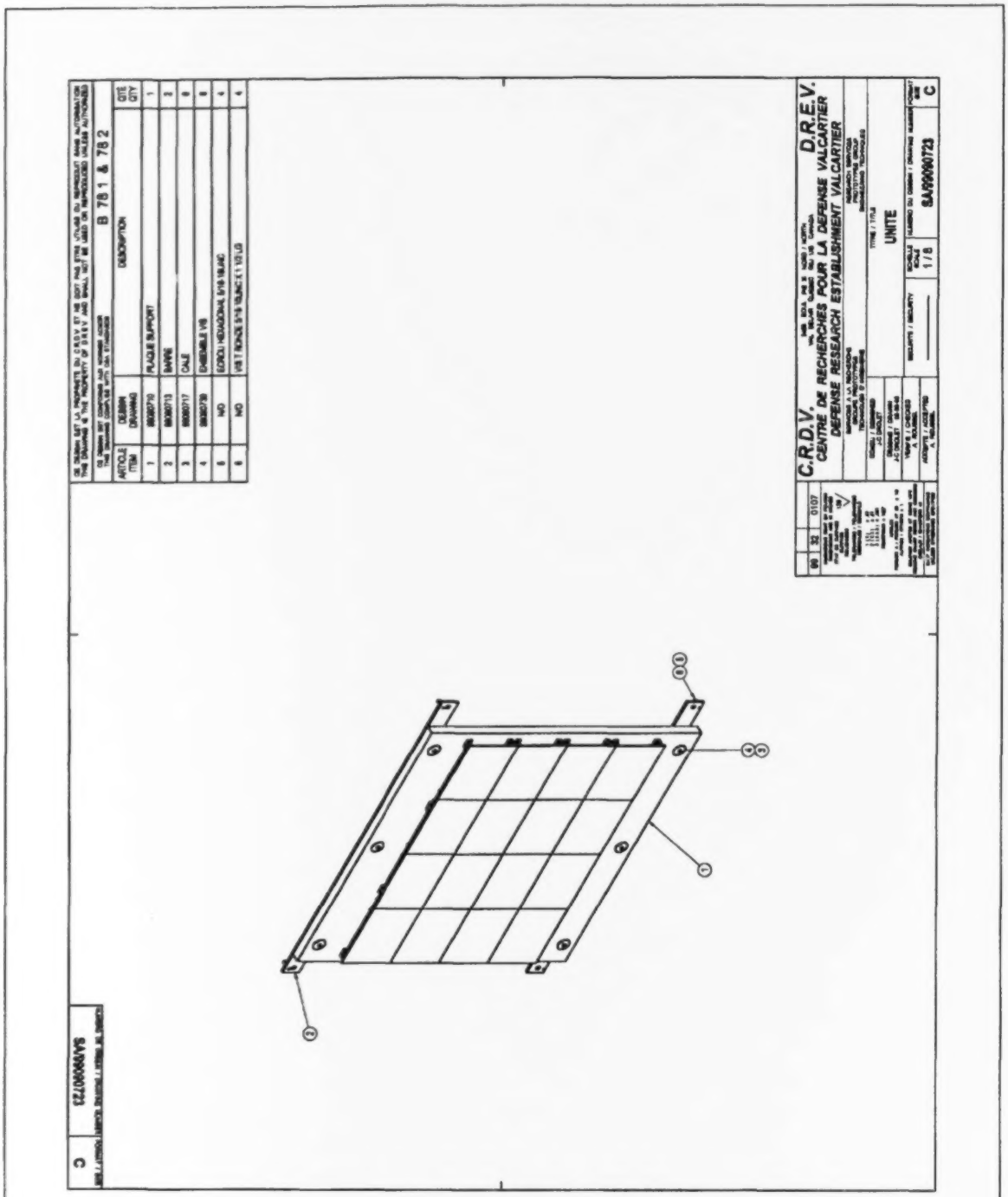

FIGURE A5 - TFT-LCD array mounted on honeycomb plate

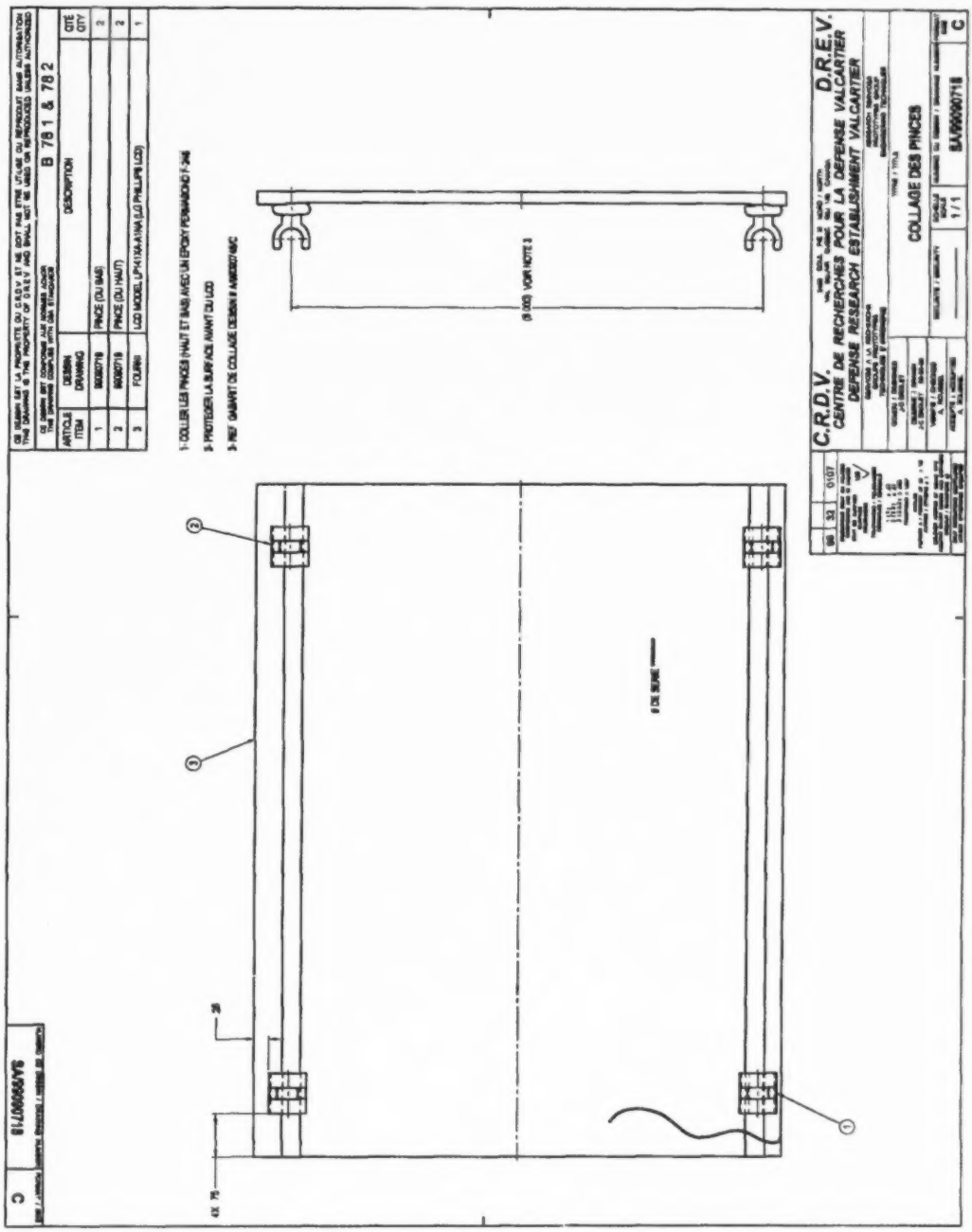

FIGURE A6 - TFT-LCD with rear attachment details

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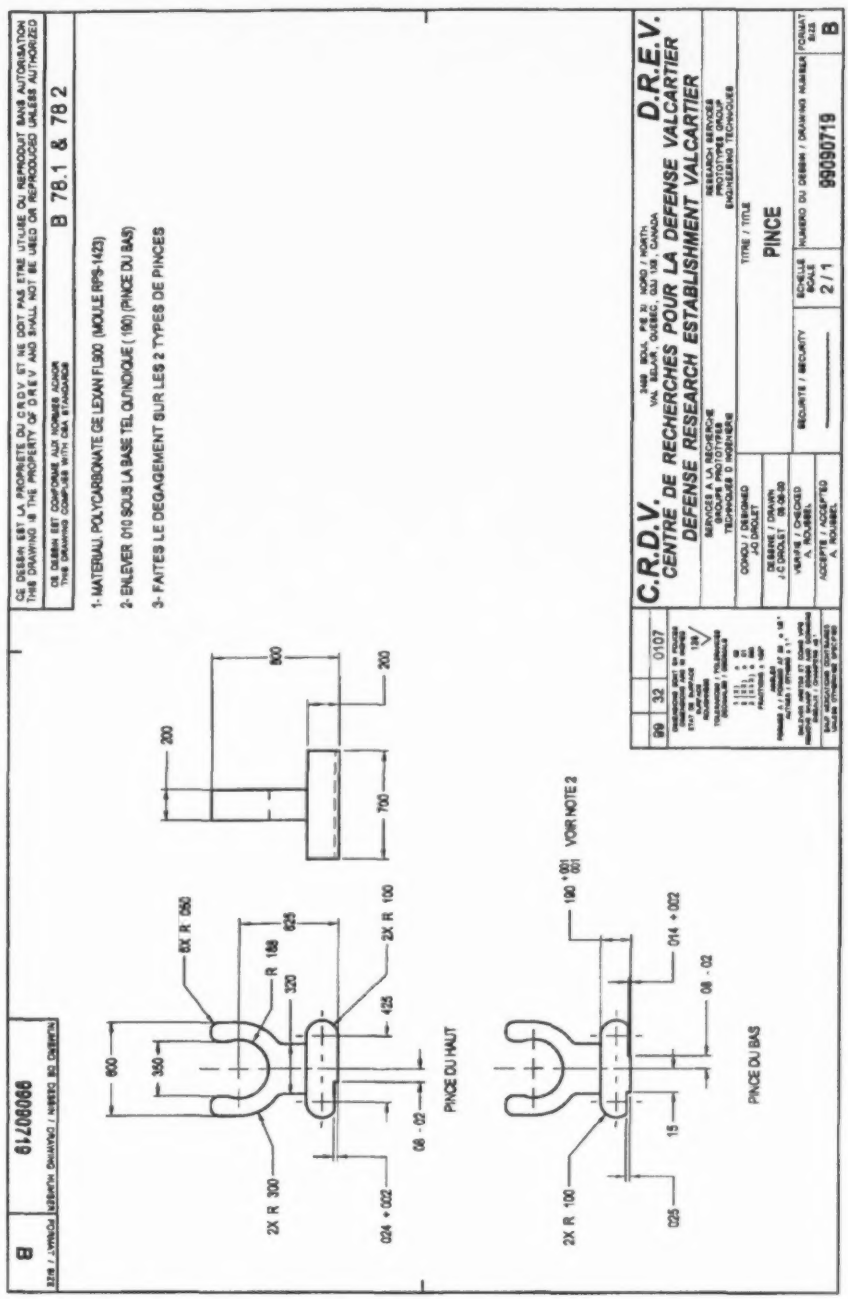
C.R.D.V.
CENTRE DE RECHERCHES POUR LA DEFENSE VALCARTIER
DEFENSE RESEARCH ESTABLISHMENT VALCARTIER
D.R.E.V.
PINCE
99090719
B 78.1 & 78 2
1- MATERIAU: POLYCARBONATE GE LEXAN FL900 (MOULE RP9-1423)
2- ENLEVER 010 SOUS LA BASE TEL QU'INDIQUE (190) (PINCE DU BAS)
3- FAITES LE DEGAGEMENT SUR LES 2 TYPES DE PINCES
PINCE DU HAUT
PINCE DU BAS
VOIR NOTE 2

FIGURE A7 - Rear attachment details

APPENDIX B

LG-Philips's LP141XA Specifications

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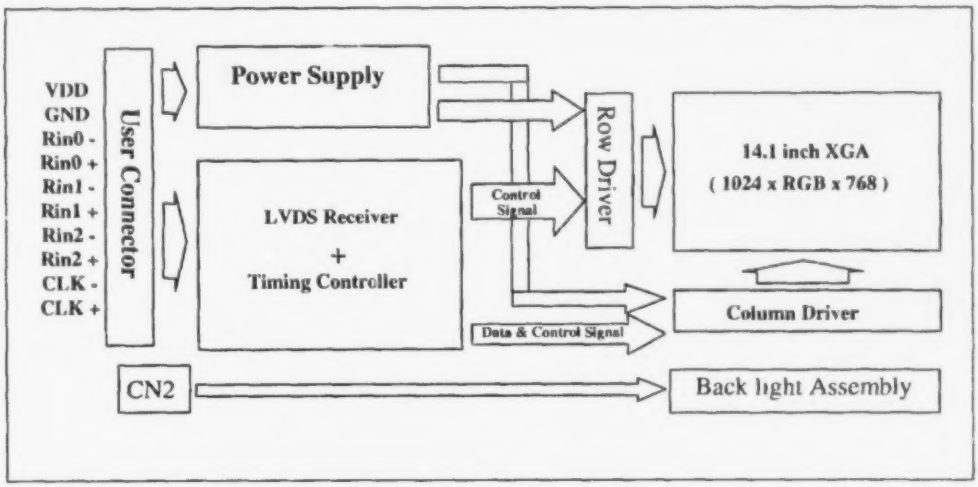
LG LCD Inc. LP141XA-A1 / Liquid Crystal Display

Product Specification

General Description

The LG Electronics model LP141XA-A1 LCD is a Color Active Matrix Liquid Crystal Display with an integral Cold Cathode Fluorescent Tube (CCFT) back light system The matrix employs a-Si Thin Film Transistor as the active element It is a transmissive type display operating in the normally white mode This TFT-LCD has a 14 1 inch diagonally measured active display area with XGA resolution (768 vertical by 1024 horizontal pixel array) Each pixel is divided into Red, Green and Blue sub-pixels or dots which are arranged in vertical stripes Gray scale or the brightness of the sub-pixel color is determined with a 6-bit gray scale signal for each dot, thus, presenting a pallet of more than 262,144 colors

The LP141XA-A1 LCD is intended to support applications where low power consumption, weight and thickness are critical factors and graphic displays are important In combination with the vertical arrangement of the sub-pixels, the LP141XA-A1 characteristics provide an excellent flat panel display for office automation products such as portable computers



General Display Characteristics

The following are general feature of the model LP141XA-A1 LCD,

Active display area	14 1 inch diagonal
Outsize dimensions	298 5 W x 227 5 H x 5 8 D mm Typ
Pixel pitch	0 279 mm x 0 279 mm
Pixel format	1024 horiz. By 768 vert pixels RGB stripe arrangement
Color depth	6-bit
Display operating mode	transmissive mode, normally white
Surface treatment	hard coating (3H), anti-glare treatment of the front polarizer

Version 1.1 12 / Feb. /1999

Courtesy of LG Philips LCD Co , Ltd.

FIGURE B1 - LP141XA General description

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Maximum Ratings

The following are maximum values which, if exceeded, may cause faulty operation or damage to the unit.

Table 1 ABSOLUTE MAXIMUM RATINGS

Parameter	symbol	Values		Units	Notes
		Min	Max		
Power Input Voltage	V_{DD}	0	4.0	Vdc	at 25°C
Logic Input Voltage	$V_{I,H}$	-0 3	V_{DD}+0 3	Vdc	at 25°C
Operating Temperature	T_{OP}	0	+50	°C	1
Storage Temperature	T_{ST}	-20	+60	°C	1

Note 1 The Relative Humidity must not exceed 80% non-condensing at temperatures of 40°C or less
At temperatures greater than 40°C, the wet bulb temperature must not exceed 39°C
At low temperature the brightness of CCFL drop and the life time of CCFL become to be short
2 Under no condition should the unit be exposed to corrosive chemicals

Electrical Specifications

The LP141XA-A1 requires two power inputs One is employed to power the LCD electronics and to derive the voltages to drive the TFT array and liquid crystal The second input which powers the backlight CCFT is typically generated by an inverter The inverter is an external unit to the LCD

Table 2 ELECTRICAL CHARACTERISTICS:

Parameter	Symbol	Values			Units	Notes
		Min	Typ	Max		
MODULE						
Power Supply Input Voltage	V_{DD}	3 0	3 3	3 6	Vdc	
Power Supply Input Current	I_{DD}	-	410	570	mA	1,2
Ripple/Noise	-	-	60	100	mV	
Differential input voltage - High	V_{IH}	-	-	100	mV	3
for receiver threshold Low	V_{IL}	-100	-	-	mV	
BACKLIGHT						
Backlight Input voltage	V_{BL}	850	725	680	V_{RMS}	4
Backlight Current	I_{BL}	3 0	5 0	6 0	mA	
Established starting Voltage				1170	V_{RMS}	25±2°C, 5
				1450	V_{RMS}	0°C
Operating Frequency	F_{BL}	40	60	80	KHz	
CCFL Life Time		10,000			Hours	● I_{BL}= 6mA

Notes 1 The current draw and power consumption specified is for 3 3 Vdc at 25°C
2 Typical value is measured when displaying black screen
Maximum power situation measured with alternating vertical lines by 2 black white pattern
3 LVDS common mode voltage, VCM=1 2V
4 The backlight power consumption shown above does not include loss of external inverter
5 The voltage of inverter is more than the established starting voltage

Courtesy of LG Philips LCD Co , Ltd.

FIGURE B2 - LP141XA Electrical specifications

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Optical Specifications

Optical characteristics are determined after the unit has been 'ON' and stable for approximately 30 minutes in a dark environment at 25°C. The values specified are at an approximate distance 50cm from the LCD surface at a viewing angle of Φ and θ equal to 0°.

Table 3. OPTICAL CHARACTERISTICS

Parameter		Symbol	Values			Units	Notes
			Min	Typ	Max		
Contrast Ratio		CR	150	250	-	-	1
White Surface Brightness	IBL=6.0mA	SB_{WH}	100	120	-	cd/m^2	2
Brightness Variation		SB_V	-	-	1.80		3
Response Time	Rise Time	Tr_R	-	20	40	msec	
	Decay Time	Tr_D	-	30	50	msec	
Color Coordinates	RED	x	0.542	0.572	0.602	-	6
		y	0.320	0.350	0.380	-	6
	GREEN	x	0.267	0.297	0.327	-	6
		y	0.519	0.549	0.579	-	6
	BLUE	x	0.122	0.152	0.182	-	6
		y	0.110	0.140	0.170	-	6
	WHITE	x	0.271	0.301	0.331	-	6
		y	0.312	0.342	0.372	-	6
Viewing Angle (CR>10:1)	x axis, right (Φ=0°)	θ	45			degree	5
	x axis, left (Φ=180°)	θ	45			degree	5
	y axis, up (Φ=90°)	θ	10			degree	5
	y axis, down (Φ=270°)	θ	30			degree	5

Notes 1 Contrast Ratio (CR) is defined mathematically as

$$\frac{\text{(Surface Brightness with all white pixels)}}{\text{(Surface Brightness with all black pixels)}}$$

2 Surface brightness is 5 spot average of measurement across the LCD surface 50cm from the surface with all pixels displaying white.

3 The variation in surface brightness, SB_V is determined by measuring B_{ON} at each test position 1 through 13, and then dividing the maximum B_{ON} by the minimum B_{ON}

$$\frac{\text{Maximum } (B_{ON1}, B_{ON2}, \ldots B_{ON13})}{\text{Minimum } (B_{ON1}, B_{ON2}, \ldots B_{ON13})}$$

4 Response time is the time required for the display to transition from white to black (Rise Time, Tr_R) and from black to white (Decay Time, Tr_D).

5 Viewing angle is the angle at which the contrast ratio is greater than 10. The angles are determined for the horizontal or x axis and the vertical or y axis with respect to the z axis which is normal to the LCD surface.

6 Color Coordinates can be changed according to color filter. (In case of changing color filter, we will tell our customer.)

Courtesy of LG.Philips LCD Co., Ltd

FIGURE B3 - LP141XA Optical specifications

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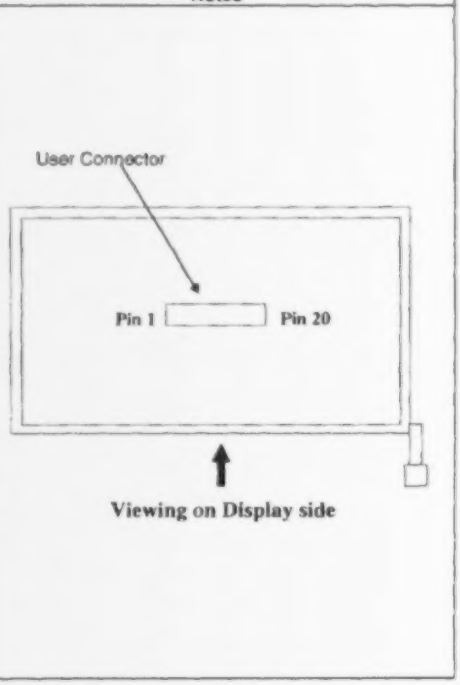
Interface Connections

This LCD employs two interface connections, a 20 pin connector is used for the module electronics and a two pin connector is used for the integral backlight system

The electronics interface connector is a model FI-SEB-20P-HF or equivalent

The pin configuration for the connector is shown in the table below

Table 4 MODULE CONNECTOR PIN CONFIGURATION

Pin	Symbol	Description	Notes
1	VDD	Power supply, 3.3V	
2	VDD	Power supply, 3.3V	
3	GND	Ground	
4	GND	Ground	
5	RinO -	Receiver signal (-)	
6	RinO +	Receiver signal (+)	
7	GND	Ground	
8	Rin1 -	Receiver signal (-)	
9	Rin1 +	Receiver signal (+)	
10	GND	Ground	
11	Rin2 -	Receiver signal (-)	
12	Rin2 +	Receiver signal (+)	
13	GND	Ground	
14	CLK -	Clock signal (-)	
15	CLK +	Clock signal (+)	
16	GND	Ground	
17	NC	Reserved	
18	NC	Reserved	
19	GND	Ground	
20	GND	Ground	

Notes. 1 All GND (ground) pins should be connected together and to GND which should also be connected to the LCD's metal frame

2 All V_{DD} (power input) pins should be connected together

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FIGURE B4 - LP141XA Interface connections

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Interface Connections (cont'd)

The backlight interface connector is a model BHSR-02VS-1, manufactured by JST The mating connector part number is SM02B-BHSS-1-TB or equivalent The pin configuration for the connector is shown in the table below

Table 5 BACKLIGHT CONNECTOR PIN CONFIGURATION

Pin	Symbol	Description	Notes
1	HV	Lamp power input	1
2	LV	Ground	2

Notes 1 The input power terminal is white

2 The ground terminal is black

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FIGURE B5 - LP141XA Interface connections (cont.)

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Signal Timing Specification

Interface Signal Timing

This is the characteristics of the interface timing parameters LVDS input timing and LCD interface timing diagrams are shown in 7 1 and 7 2
LP141XA-A1 with LVDS transmitter recommend to connect to the Display Enable, Horizontal sync, Vertical sync, Clock signal from Video signal controller to input of Transmitter simultaneously

ITEM	SIGNAL	ITEM	SYMBOL	MIN.	TYP.	MAX.	UNIT
LVDS Timing (Note 1)	Clock	Frequency	f_{CLKIN}	-	65	66 6	MHz
		Period	t_{CLKIN}	15	15 4	-	ns
	LVDS Low to High time	Transition time	LLHT	-	0 75	1 5	ns
	LVDS High to Low time	Transition time	LHLT	-	0 75	1 5	ns
	Set up time, serial bits	Receiver Input Strobe Bit 0	t_0	-0 4	0	0 3	ns
		Receiver Input Strobe Bit 1	t_1	1 8	2 2	2 5	ns
		Receiver Input Strobe Bit 2	t_2	4 0	4 4	4 7	ns
		Receiver Input Strobe Bit 3	t_3	6 2	6 6	6 9	ns
		Receiver Input Strobe Bit 4	t_4	8 4	8 8	9 1	ns
		Receiver Input Strobe Bit 5	t_5	10 6	11	11 3	ns
		Receiver Input Strobe Bit 6	t_6	12 8	13 2	13 5	ns
LVDS Transmitter Input (note 2-4)	DENA	Low width	t_{WDE}	100	-	-	t_{CLKIN}
		Horizontal Front Porch	t_{HFP}	0	-	-	t_{CLKIN}
		Horizontal Back Porch	t_{HBP}	5	-	-	t_{CLKIN}
		Vertical Front Porch	t_{VFP}	0	-	-	t_H
		Vertical Back Porch	t_{VBP}	4	-	-	t_H
	HD	Frequency	f_H		48 5	55 9	Hz
		Period	t_H	1100	1340	-	t_{CLKIN}
		Low width	t_{WH}	1	-	-	t_{CLKIN}
	VD	Frequency	f_V			62	Hz
		Period	t_V	772	809	-	t_H
		Low width	t_{WVL}	0 5	-	-	t_H

Note 1 Measurement is made at panel side flex connector with dummy 100 ohm termination
2 Polarities of HD and VD are negative
3 DENA should always be positive polarity
4 CLKIN should appear during all invalid period HD should appear during invalid period of the frame cycle

Courtesy of LG.Philips LCD Co., Ltd.

FIGURE B6 - LP141XA Signal timing specification

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Mechanical Characteristics

The chart below provides general mechanical characteristics for the model LP141XA-A1 LCD The surface of the LCD has an anti-glare coating to minimize reflection and a 3H hard coating to reduce scratching In addition, the figure below is a detailed mechanical drawing of the LCD Note that dimension are given for reference purposes only

Outside dimensions	Width	298 5 mm typ
	Height	227 5 mm typ
	Thickness	5 8 mm typ
Active Display area	Width	285 7 mm
	Height	214 3 mm
	Diagonal	14 1 inch
Weight		590 g max

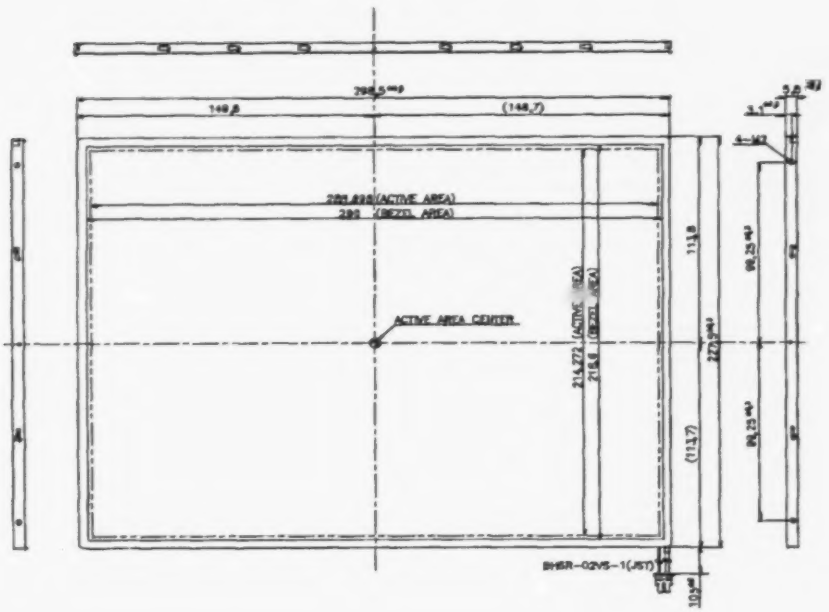

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FIGURE B7 - LP141XA Mecanical characteristics

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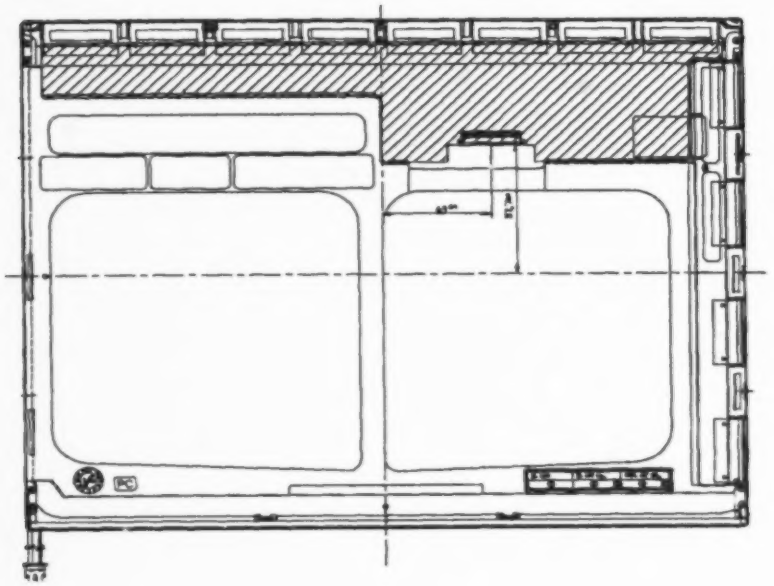

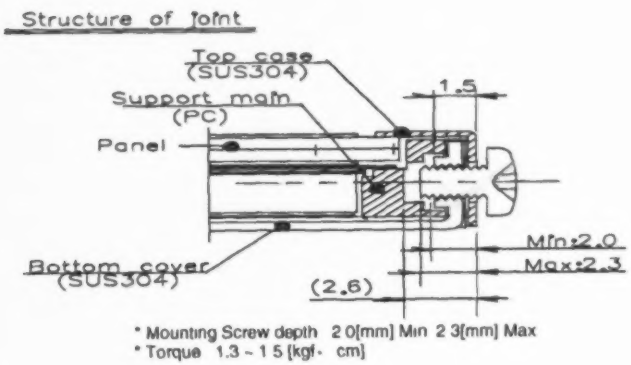

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FIGURE B8 - LP141XA Mecanical characteristics (cont.)

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LIST OF ACRONYMS

A/D	Analog-to-Digital
AfCaTo	Affichage pour cartes topographiques
AfCaTo MkII	AfCaTo de seconde génération
ASIP	All-Source Intelligence Producer
B/W	Black and White
CCFL	Cold Cathode Fluorescent Lamp
CCIS	C&C Information System
CF	Canadian Forces
CIE	Commission internationale de l'éclairage
COTS	Commercial-Of-The-Shelf
CRT	Cathode Ray Tube
C&C	Command and Control
DC	Direct Current
DFP	Digital Flat Panel
DMD	Digital Micromirror Device
dpi	dots per inch
DRDC Valcartier	Defence R&D Canada – Valcartier
DVI	Digital Visual Interface
FF	Fill Factor
FPD	Flat Panel Display
GUI	Graphical User Interface
JWID	Joint Warrior Interoperability Demonstration
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LVDS	Low Voltage Differential Signalling
NDS	National Display Systems
PDP	Plasma Display Panel
ppi	pixels per inch
RGB	Red Green Blue
TEC	Tube à écran cathodique
TFT-LCD	Thin Film Transistor LCD

ToMaDi	Topographical Map Display
ToMaDi MkII	Second generation ToMaDi
TTL	Transistor to Transistor Logic
VGA	Video Graphics Array
XGA	eXtended Graphics Array

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(U) This technical memorandum describes in detail the development of a 2nd generation Topographical Map Display (ToMaDi MkII) The ToMaD display system is an evaluation prototype, made from a 4 by 4 matrix of colour Thin Film Transistor - Liquid Crystal Display (TFT-LCD) and desigr study alternatives to topographical paper maps for Command and Control (C&C) applications Because ToMaDi MkII is a touchscreen computer disp contributes to the digitization of the battlefield project The brightness, contrast ratio and viewing angle are similar to those of a Cathode Ray Tube (display But, contrarily to CRT, its shallow depth allows its usage in confined locations while maintaining a high portability Up to now, the MkII prototyp shown very good characteristics that allow its use in specific operational scenarios. The value of ToMaDi MkII was confirmed by its utilization in three military exercises In summary, the ToMaDi MkII makes electronic mapping a reality.

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